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INSTINCT AND INTELLIGENCE

BY

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Introduction by

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BF671.H76 ST. JOSEPH'S UNIVERSITY STX
Instinct and intelligence
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New York

THE MACMILLAN COMPANY

1929

American edition published, April, 1929
Reprinted, August, 1929
Reprinted, November, 1929

BF671
H66

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Printed in the United States of America

PREFACE

In this book I endeavour to throw some light on the difficult study of animal behaviour. How far are animals mere machines ; how far do they think in a manner like ourselves ? Are their minds something altogether distinct, or are they in essential characters comparable with the mind of man ? My authority to discuss this interesting subject is based on prolonged personal observation. For seventeen years I have collected facts in that most fruitful of all regions, the jungles of the Oriental tropics. This volume represents a digestion of these facts, together with observations bearing on the subject taken from distinguished and unimpeachable authorities. The deductions which these facts lead me to make must necessarily be of a controversial nature. Many will say that I go too far in the effort to demonstrate the possession of intelligence. Nevertheless, to my mind, the deductions are sound, and are forced upon us by the nature of the facts.

I have, in common with many Naturalists, to express my thanks to Professor Poulton. It would indeed be difficult to estimate how much those entomologists who labour in the Tropics owe to the enthusiasm of Professor Poulton. It is no exaggeration to say that the assistance and stimulus and encouragement he gives has made him the focus for that stream of observations which flows in from entomologists all over the world.

R. W. G. H.

ARE INSECTS INTELLIGENT?

An Introduction to "Instinct and Intelligence"

By

BERTRAND RUSSELL[1]

This book is very much more interesting than its title would lead one to expect. Titles of this general sort usually introduce merely argumentative discussions which add nothing to our data; this book, on the contrary, is based upon long and patient first-hand observation of the behaviour of insects and spiders. It is a book which adds to our knowledge of facts and not merely to our power of talking impressively. Contrary to many authorities, the author maintains that insects are not purely instinctive in their behaviour, but have something that may be called intelligence. The facts which he adduces in support of this conclusion are very remarkable, and I for one do not see how they can be interpreted on a purely instinctive basis.

Insects are, as everyone knows, the most noteworthy examples of complicated instinctive behaviour. With many of the higher animals it is difficult to distinguish with certainty between instinct and education, but education can play no part in those numerous kinds of insects among which one generation is never acquainted with another. Moreover, many of the most remarkable instincts of insects are concerned with acts performed only once in a lifetime, and therefore incapable of being learnt by experience. It is all the more remarkable that even among insects traces of intelligent adaptability to circumstances should be found.

The author begins with observations that fit into the conventional scheme, showing the perfection of instinct in normal circumstances, the inflexibility of its behaviour-pattern, and its extraordinary stupidity in unusual circum-

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stances. Take, for instance, his account of an experiment made by Fabre on a certain kind of caterpillar which has a habit of marching in a procession, making a thread as it goes. Fabre caused a number of caterpillars of this species to march round the circumference of a large vase.

"The procession formed a string around it, a completely closed circle of caterpillars, no leader, all followers, an endless file along an endless track." He had brought about a state of affairs that could never occur in ordinary life.

"What happened? How did the procession behave on this interminable path? Did they go on for an hour or two, then realize that they gained nothing and break away on another road? The experiment began on the 30th of January. At midday Fabre got them on the circle. All that day they went round and round. Evening came, and they were still at it. Fabre was stupefied, amazed. Next morning he saw the gyration continuing, and so on throughout that day. The third day came. Still it went on. There was frost in the air, and the cold numbed the caterpillars. They had no food, and starvation weakened them. At night the call of the nest allured them, yet they could not break from the everlasting circle and strike a new course of their own. Day after day they stuck to their circling, tied to that fatal thread. This went on for seven days and nights. On the 6th of February deliverance came. More apparently by accident than by design, some of them managed to break from the circle and escape the interminable routine. The spell ended on the eighth day. Eighty-four hours had been spent in walking. They had travelled more than a quarter of a mile."

There is a curious incapacity for performing one kind of act at a time when the animal's instinct is directed towards another kind. If, for example, you destroy the part of a spider's web which he makes first at a time when he is making the latter part, he is incapable of repairing the damage.

Many insects deposit their eggs in holes which they afterwards close up; if after they have laid their eggs and before they have closed the hole you take the eggs out, the insect, even though it can see the eggs, will proceed to close the hole with all care, that being the act to which its instinct prompts it, at that moment.

A great deal of nonsense has been talked about the unerring wisdom of instinct; as a matter of fact instinct is very easily deceived. The Peckhams took the egg bag off a spider and gave it lead shot instead; although the lead shot weighed three or four times as much as the egg bag, the spider accepted it as a suitable object of maternal solicitude. Bees and wasps will mistake the flowers on a wallpaper for real flowers. By sounding a tuning fork near a spider you can persuade him that he hears a fly buzzing; he will seize the tuning fork and bite it under the impression that he is going to get a juicy morsel. We are always told that the social instincts of bees and ants are infallible, and that there are none of those political maladjustments to which we are accustomed in human society. Yet it seems that even among ants proletarian revolts are not unknown:

"Forel observed a similar incident when studying the slave-making ants of Switzerland. *Polyergus* is the ant in question. It keeps in its nest a crowd of slaves, and fights furiously with other ants. When engaged in battle, they get blind with rage. Not only do they assault the enemy, but they bite everything they come in contact with, bits of earth, bits of wood, larvae, cocoons, even their own companions and their own slaves. So lost do they get in their mad excitement that they can no longer recognize their road. Their slaves try to calm them and direct them, but not till the fury of battle is over can they find their way about like normal ants.

"On another occasion he met with *Polyergus* deliberately destroying its own slaves. Now, this does seem very extraor-

dinary. For the ant is absolutely dependent on its slaves The slaves feed it, tend its larvae, even build its nest and carry it about. Also the slaves accept their bondage with every sign of passive resignation. In fact, masters and slaves live together in what seems like perpetual peace. Yet here is what Huber witnessed: a complete reversal of ordinary affairs. On one warm day in a *Polyergus* nest the slaves began to get unruly. They seized their masters, even bit at them, and dragged them far outside the nest. The masters' bodies were too tough to get injured. Nevertheless, they resented the rebellion. The slaves, after dragging them some distance, released them. But sometimes they continued their vicious bitings. Then the master rose against the slave and killed it by piercing the brain in the same way as it kills its enemies. There must surely be an error somewhere to bring about such abnormal events."

What more can be needed to show that the intelligence of ants resembles that of human beings? Intelligence is a somewhat vague word, but what is meant by it when the behaviour of animals is being interpreted is adaptability to circumstances and capacity for learning by experience. In this sense the instances given by Major Hingston are, it seems to me, quite adequate to prove his point. Certain ants, for example, had to cross a tramway to get to their food; after a number of them had been crushed in crossing the rails they made tunnels under them, and when these tunnels were blocked up, they made other tunnels. This is a clear case of the modification of behaviour owing to experience. The following example, if it does not prove intelligence, certainly proves some very remarkable capacity. Major Hingston cut a grasshopper into three bits, of which the second was twice as bulky as the first and the third twice as bulky as the second. He gave the bits to three separate ants from the same nest; each ant went back to the nest and sent out a party to its own bit. 28 ants went for the first bit, 44 for

the second, and 89 for the third; that is to say, the number of ants was very nearly proportional to the bulk of the bits. Ants can be tamed, and when tamed behave differently from wild ants. Mr. Donisthorpe, for example, spent seventeen years in taming a certain colony of ants, and at the end of that time most of them had completely lost the habit of rolling themselves into a ball when frightened. Miss Fielde divided a nest into two parts, treating the ants in one half with kindness and in the other half with severity; those that were treated with kindness gave up all attempts to bite her and ceased to be afraid of her, while the others did exactly the opposite. Major Hingston concludes that "These creatures possess not only choice, but, in addition, no little judgment in the way that choice is used."

Instances are given of adaptability to circumstances among other kinds of insects as well as ants. It is clear that the reign of instinct is not so inflexible as has often been supposed.

There is much evidence that insects have a sense unknown to us, which is shown in their sense of direction. Locusts, for example, will fly over the sea in a constant direction even during the night, and experiments are given to show that with ants direction is a more powerful factor than scent in enabling them to find their way. The sense of direction in insects has long been a puzzle. Darwin suggested a magnetic field in the neighbourhood of an insect. So far this matter remains a mystery.

There is a chapter on insect memory which gives a number of interesting data as to the way in which bees and wasps remember the situation of their nests. There are curious data as to how long a spider will remember its egg bag if it is first removed and then restored after an interval. It was found that there are variations of memory within the same species; some could only just remember after three hours, some remembered for twenty-four hours, forty-eight hours was too long for any of them. But when it is said that the

spiders remembered their egg bags, all that is meant is that they took them back and behaved towards them in the proper manner. That, of course, is all that can be meant in such cases, since it is all that can be observed. Major Hingston concludes his chapter on memory by saying: "We cannot explain psychic phenomena by reducing things to physical and chemical laws. Even insect psychology has something else. It has memory and conscious mind." When he says this, he is saying something that goes beyond what his data warrant. Take, for instance, the facts about the egg bags. How does he know that the spiders did not react to an olfactory stimulus which grew gradually fainter? It is still an open question whether human behaviour cannot be explained by physical and chemical laws; therefore we cannot be sure that the behaviour of spiders is not so reducible, however much it may resemble the behaviour of men.

Major Hingston's views on mental evolution are similar to those of Samuel Butler and of Semon. He thinks that instinct began in a reasoned act which gradually became unconscious. This, of course, assumes the inheritance of acquired characters in a very extreme form, and also involves a high degree of intelligence in the lowest animals. Can it be supposed, for example, that reproduction was intelligent before it became instinctive? Major Hingston is entirely right, however, in insisting that instinct is variable and therefore subject to evolution. Of this he gives many illustrations, of which perhaps the most remarkable is the following: A certain species of fly which lives in India possesses the highly advantageous habit of sitting on the bases of prickly-pear thorns, where the spines protect it from all but the minutest enemy. But the prickly-pear was introduced into India at the beginning of the nineteenth century, so that this habit must have been acquired quite recently.

Whether one agrees or disagrees with the general psychology and philosophy of Major Hingston's conclusions,

the book remains one of the greatest interest and value, since his data are largely derived from personal observation and are always kept completely separate from the arguments which he bases upon them. The book is fascinating reading.

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INSTINCT AND INTELLIGENCE

CHAPTER I

THE PROBLEM

The problem before us is a very old one. Are the lower animals blind creatures of impulse or are they rational beings?

The time was when a simple answer could be given. Man was the one rational being. The rest of creation were only brutes. Those days have gone for ever. We no longer have these simple cut-and-dried definitions. We regard life nowadays as far more homogeneous. Sharp delimitations are becoming impossible. All animal life, psychologically as well as structurally, is blending in a common stream.

I am here concerned with the psychological aspect. I deal exclusively with animal behaviour and the mental states which such behaviour involves. Do animals low in the scale of nature reason? How do they solve their problems of existence? Are they mere thoughtless automatons, or are they intelligent beings like ourselves?

Instinct and Intelligence. I enter on a thorny and difficult question. I face a problem which has interested the most distinguished naturalists and on which we find the most conflicting views. Darwin grappled with it. One of the most brilliant chapters

in the *Origin* indicates the long thought that he gave to the subject. Romanes and Lloyd Morgan have discussed it in detail. Huber, Wasmann, Wheeler have attacked it. Some of the most acute investigators of the Tropics, Wallace, Bates, Belt, the Peckhams, have shown their interest in a crowd of observations. Forel has enriched it by his studies in Switzerland; Bouvier in France; Ferton on the islands and shores of the Mediterranean. But far above all stands Henri Fabre. The French naturalist spent a lifetime probing into instinct. His record of achievement is without comparison. I think at times he has been too dogmatic; I regard some of his assertions as unjustified; in this volume I shall frequently contest his views. It is with feelings of diffidence that I differ from this authority. When I do so it is with sincere humility, and with no lessened admiration for those wonderful discoveries with which he has illuminated a new world. Fabre, when he differs from other naturalists, insists on the necessity of field observations. He scorns the scientist in the armchair. He goes to the animal and questions it. I fully agree with the solidity of this attitude. When I differ from him I do so according to his principles. My evidence is taken direct from the field.

My first difficulty, when confronted with this psychological problem, is the difficulty in supplying accurate definitions. What is instinct? What is intelligence? These words have been the subject of hundreds of definitions and have been given innumerable varieties of meaning. Some definitions are so technical as to be unintelligible; others are demonstrably inexact. Certainly many good definitions have been given, yet not one of them is entirely satisfactory. It is not my intention to criticize or discuss them, especially as I regard the words *Instinct* and *Intelligence* as being incapable of

accurate definition. Darwin made no attempt to define Instinct. He refrained from it, as he refrained from defining Species. Every one knows what is meant by a species. One clearly appreciates the meaning of the words when one says that lions and tigers and leopards are three species of the cat genus. Yet if we push for a strictly accurate definition we shall find that no one can supply it. Give a group of animals to two naturalists. One will make them into ten species: the other into a hundred species. Why? Because a species is an indefinable entity. It graduates at the one extreme into the genus, at the other into geographical races.

So it is with Instinct. Everybody understands what is meant when one speaks of an instinctive action. There is a perfectly clear idea in the mind when we say that instinct compels a bird to migrate or that by instinct a spider constructs its web. But try to define Instinct, and it will be found to be impossible. One man's definition will include what another man's will exclude. For Instinct, like Species, is indefinable. It graduates at the one extreme into intelligence, at the other into unconscious reflex action.

Though we cannot define it with strict accuracy, yet that does not prohibit the subject from discussion. Darwin gave no clear definition of Species, yet that did not prevent him from writing the *Origin*. There are certain elements in an instinctive action which separate it sharply from intelligent behaviour. We may safely make the following assertions.

1. An instinctive action is independent of instruction. A spider makes its web though it may never have seen one. A solitary caterpillar hatched out in a box manufactures the typical cocoon.

2. An instinctive action is unassociated with any reasoning. The spider does not think out how to make

a web, nor the caterpillar how to manufacture a cocoon.

3. An instinctive action has an end in view, yet of that end the individual is ignorant. The spider spins, but it does not know that it is making an insect-catching apparatus; the caterpillar weaves, but it can know nothing of the chrysalis for which the shelter is being made.

Instinct, therefore, means blindness and ignorance. Often it exhibits the most amazing perfection. We are sometimes astounded at the complicated acts which instinct performs with absolute precision. We are astounded because they are done in ignorance. As Fabre puts it:—"There is no calculation, no premeditation, but simply blind obedience to the general law of harmony."

Turn now to intelligence. Here we are up against something quite different. An intelligent act implies conscious knowledge. A creature that behaves in an intelligent manner must recognize the relation between cause and effect. It must possess the faculty of choosing, and, when faced with two alternatives, of adopting one course in preference to another. Fabre puts it in the simplest way:—"Reason is the faculty that connects the effect with its cause and directs the act by conforming it to the needs of the accidental. Within these limits, are animals capable of reasoning? Are they able to connect a 'because' with a 'why' and afterwards to regulate their behaviour accordingly?"

An illustration will make my point clear. Take a spider and its geometrical web. The building of this web is an act of instinct. Why? Because the spider has never learnt the art of web-making, because it is ignorant of what it is doing, because it does not know what the web is intended for, and because all the others

of its species do exactly the same thing in exactly the same way. In fact, in this behaviour the spider is an automaton. It acts as it does, blindly, undeviatingly, accurately, yet utterly ignorant of what it is doing and of the reason why it is doing it.

Take in contrast an act of intelligence. How different would the mental outlook be if the spider could repair a hole in its web. There can be no blind behaviour here. The spider is faced with something unusual, something which instinct cannot put right. An emergency has arisen, something new, something out of the routine of life. The spider must now exert choice and recognition. It must see and understand the nature of the damage. It must take stock of what has occurred. It must pick up one thread and link it to another thread, and must do it in a workmanlike way. Because there is a hole, therefore it must mend. It must connect a 'because' with a 'why,' and regulate its behaviour accordingly.

Such is the problem which I have to consider. To what extent are animals thoughtless automata? And to what extent can they meet emergencies and deal with them in a rational way?

Is the problem worth considering? I submit that it is. The subject in itself is of intrinsic interest. No department of natural history can compare with it. The study is not the bones and skins of the museums, but animals as they exist in their natural environment, their habits, instincts, behaviour, activities; Nature as she lives and moves. Moreover all psychology is important. We cannot separate man and study him alone as if nothing else were of any value. All Nature is kin. All mind is made of one common stuff. What do we know of human physiology which has not been taught us by the lower animals? By learning the work of their bodies we have learnt to know our own. Comparative

physiology is of admitted importance; why then not consider comparative psychology? I do not maintain that the psychology of the lower animals is going to teach us all about human psychology; but one thing is certain: each can react upon the other, and we shall never understand our minds until at the same time we understand theirs.

We must select a group of animals for this particular study. Our choice unquestionably falls on insects. Of all animals they are incomparably most suitable. Their instincts display such infinite variety, they solve such innumerable complicated problems, they illustrate perfection in the highest degree. Birds and mammals cannot compare with them. Amongst birds we think of the nest-building instinct. But that in comparison is a simple procedure. Moreover it lacks the infinite variety. The caterpillar equals it when making a cocoon. It is far surpassed by other insect devices; for example, by the pitfalls manufactured by ant-lions, by the hinged doorways of trap-door spiders, by the spiral chambers of Psychid moths. Then, think of the social communities of insects. What an infinite variety of exquisite adjustments do we not find in the formicary and hive? We have builders, hunters, excavators, harvesters, road-makers, cattle-tenders, leaf-cutters, garden-growers, and innumerable other forms of activity performed with the utmost nicety and precision. There is nothing to compare with it amongst the higher animals until we come to the activities of men.

Or take my illustration of the spider's thread.[1] What a host of purposes does it not fulfil. Many kinds weave it into bags for their eggs; some make it into harnessing-

[1] In strict scientific classification spiders are not included amongst insects, but they come within the scope of our present study owing to their remarkable instincts.

ropes by which they drag these bags about. Often it serves as a suspension-rope on which a spider can drop from its web. One kind will use it as an anchoring line to prevent a sudden fall; another will employ it as a kind of float on which to drift through the air. Others weave it into a silken tunnel; others make out of it an ingenious trap-door; others turn it into a silken tent. There are others that go under water and shape it into a diving-bell; there are others that spin it into complicated networks, into cart-wheels or hammocks or widespread sheets. Then we have others that use it as a telegraph-wire; others that twist it into spiral springs; still others that make it into a lasso and hurl it round their prey.

Surely this is infinite variety. A thread of silk. Instinct does everything conceivable with it. Can we find better material for our study? Not unless we go to man himself.

One last point. What right have we to apply to insects the methods of examination which we apply to ourselves? What is our justification for judging them according to our own standards? The organization of an insect is so very different from our own. Its mental state may be fundamentally different. Therefore it must be judged in some different way. It is impossible to satisfy that kind of objection. No other plan of investigation is available. We must examine the lower animals in the same way as we examine ourselves. How? By observing a certain kind of behaviour and inferring a mental state behind it. We can never know that mental state. We cannot feel any feelings but our own. In others we can only infer their existence. Certain actions in ourselves are associated with certain feelings, therefore when we observe those actions in others we infer that the same feelings exist in them. Well and good. But can you

apply that method to the lower animals? My reply is that it is the only method. Reject it, and the problem is outside discussion. We are up against a brick wall.

The method has always been adopted, and, in spite of objectors, will continue to be adopted. Moreover it is a method fully justified. How human-like is much of the behaviour of insects! The organization of a community of ants bears on the face of it the same force as that which has shaped the human commune. Furthermore, is not all Nature kin? What right have we to set up barriers? Does not a continuity of mind as well as body run through the whole animal kingdom?

Having answered this objection, I proceed to the problem. Are insects the blind agents of irresistible impulse, or are they endowed with a share of reason?

CHAPTER II

THE PERFECTION OF INSTINCT

The perfection of instinct continually amazes us. On the surface it appears highly intelligent. Indeed, it is this false appearance of intelligence which has so often led people astray. When we remember what instinct is, a blind, inherited, thoughtless impulse, we are frequently astonished at the logical manner in which that thoughtless impulse works. My meaning on this point is best explained by means of a few striking examples. I give some from my own experiences. More elaborate illustrations might easily be found; but those which I give are less generally known and are ones which I have happened to study in the Tropics.

The Communicating Instinct of Ants

Phidole indica is a small ant common on the Indian plains. The colony makes a nest in the soil, sends out armies in search of insects which they carry dead or alive to the nest. The best way to observe their communicating instinct is to throw a caterpillar to one of these ants. The ant discovers it, carefully examines it, makes one or two attempts to drag it, then races off to the nest for help. It rushes inside, disappears from view. Within a few seconds of its disappearance a vast army of excited ants comes pouring out of the nest gate. They dash over the ground, an immense legion of them, make

straight away towards the caterpillar, reach it and surround it with a swarm. A battle ensues. Hundreds of ants besiege the caterpillar. Some hasten back for more reinforcements. Others bite at it, drag at it, shift it. In the end the caterpillar is overwhelmed by numbers and carried bodily into the nest.

This act exemplifies a perfect instinct. A single ant has brought back news. It has told the nest of its valuable discovery. The nest has an army held in readiness which it can despatch to a particular spot. Out goes the army when news arrives to gather in the spoil. The whole affair is highly remarkable. It shows throughout a most perfect efficiency. Can we gain any clearer idea as to how this perfect efficiency works?

I attempt it in this way. Another caterpillar is thrown to the ants. This time I mark with a spot of paint the ant which finds it and goes back with the news. Also I mark the exact route which this ant follows on its way to the nest. These two tricks will give us bits of information. They will show us what it is that guides the ants.

The first point which it discloses is that the ant which goes back with the news comes out in the midst of the issuing army. In other words, it does not lead out the army. On the contrary, it despatches them from the nest. I prove this point very easily. The moment the ant with the spot emerges I pick it up and throw it aside. What does the army do? It goes straight on to the caterpillar without any assistance from the marked ant. Thus the ant which finds the caterpillar does not guide the army. All it does is supply information. The army gets there on its own accord.

The second bit of information is this. We have marked the track which the ant followed on its way from the caterpillar to the nest. We now observe that the issu-

ing army follows exactly along that track. It is therefore highly probable that the army retraces the scent of that ant. A few simple experiments, detailed elsewhere,[1] easily prove that this is the case. The army gets there by means of scent. It smells its way along the track. In fact, we have the following performance. A single ant finds a caterpillar, makes its way back to the nest and leaves a scented track behind it. An army in waiting receives the information. The army first gets the smell of that ant, then pours out of the nest, then follows along the scented track which in the end brings it to the caterpillar.

Now, all this illustrates the highest instinct. In fact, it may sound a little far-fetched. Nevertheless, I intend to take it much farther, for, as yet, we have not reached the acme of perfection. While this incident is in progress ants are wandering round about the nest. The ant returning with the news of the caterpillar meets them and continues its course. Its track, however, crosses over their tracks. It may cross and recross a dozen or more of them before it gets into the nest. Now will all this crossing confuse the army? When the army is tracing back the track of that ant, will it be confused by all the other tracks which have happened to cross over it? Will it lose the smell of one particular track in the midst of the smells of all the other tracks? Not a bit of it. The army goes on without the slightest hesitation. It matters not how often the track is crossed, the army easily picks it out from the tracks of all the other ants that cross it. And since the army follows by smell, it in some way separates the smell of that track from the smells of all the other tracks in the neighbourhood. Which implies that the ant making the track possesses a distinctive smell. And since any ant can

[1] *A Naturalist in Himalaya*, pp. 67–9.

bring back news and leave a scented track, therefore the army can distinguish any ant from that of all the others in the nest.

Here then is the perfection of instinct: that each ant in the *Phidole* commune can separately distinguish all its comrades. A nest may contain a thousand individuals. To us they appear all exactly alike, yet each is separately known to one another.

The Oiling Instinct of Spiders

In this we find another instance of perfection. Fabre made some ingenious experiments to show why it was that a spider did not get entangled in its own snare. The threads of a cartwheel snare are sticky. Anything that touches them immediately adheres. But not the spider. It walks freely on the sticky filaments of its own web. The reason is that the spider has an oily coat. Fabre snipped off a spider's leg. He applied it to a thread. It did not stick. He then soaked it in disulphide of carbon. This dissolved the oily film, with the result that the leg, like any other substance, immediately stuck to the thread. I have repeated these experiments. They fully substantiate the observations of Fabre.

But what did not come beneath the observation of Fabre was how and where the oily film was produced. No doubt he thought it was a natural exudation, a kind of sweat on the creature's skin. But this is not so.

The oiling is done by the spider itself, a most interesting instinctive act.

It occurs in this way. An immense spider, *Nephila maculata*, lives beneath the trees in an Indian jungle. She has a span of over 6 inches, and makes a web as big as the wheel of a car. Moreover, she is very deliberate in her movements, and shows us exactly how this oiling

is done. The oiling commences at sunset when the spider is about to build a snare. She hangs by a leg to one of the threads. Then she carries another leg forward and draws it slowly between her jaws. As it passes between them it gets moistened with oil squeezed out from the salivary glands. The oiled leg is then carried backward and made to stroke the end of the abdomen. Another leg is then brought forward, moistened with oil in the same way, then made to stroke one of the opposite legs. Then a third leg is oiled, then a fourth. Each time the oil is carried backward and applied to some part of the body. It is a very tedious operation. *Nephila* works at it for over an hour. Such is the way this spider gets her oil. She secretes from her mouth a special stuff which prevents her sticking to her threads.

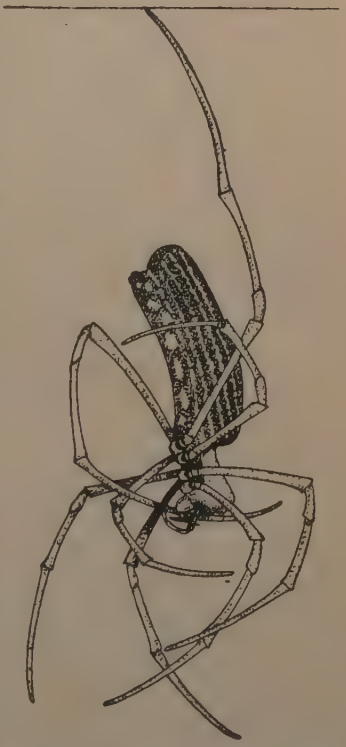

FIG. 1.—*Nephila maculata* oiling herself.

But there is another point about it which illustrates better the perfection of instinct. The spider does not smear her oil just anyhow. She puts it only at special spots. Her legs, for example, are carefully smeared. Another spot that gets thickly oiled is the spinning apparatus at the end of her abdomen. Then, all around

her mouth, her jaws and palps are smeared with a lavish coat. But the rest of her body is quite neglected. None goes on her head, her thorax, her back. Why is this? It is an example of instinctive economy. The spider oils only those parts of her body which are likely to touch the web. Those parts are her legs, her jaws and her spinning apparatus. Her legs will touch it whenever she walks, her spinning apparatus when she fixes a thread, her jaws when she grips the prey. These parts, therefore, get it lavishly. The rest of her body does not get a drop. Presumably she has only a limited supply. Hence her instinctive display of prudence. She oils only the essential spots.

Here again we find instinctive perfection. We see it in the nature of the strange device and the foresight that allows nothing to go to waste.

Instinctive Foresight

Instinct often shows remarkable foresight, which again goes to illustrate perfection. I will give only a few examples out of numbers that might be supplied.

Take the commonest instance, the food plant of a butterfly. The butterfly seeks out one species of plant on which to lay her eggs. She acts as if she knew beforehand that this particular species of plant is the only one on which her caterpillar will feed. Moreover, one would think she had botanical knowledge. For her caterpillar will sometimes feed on related plants, on species of the same natural order which superficially have little resemblance but which come together in a scientific classification. And the butterfly acts as if she knew this relationship, placing her eggs on these related plants and not on any other kinds. The Common White Butterfly lays on the cabbage, but sometimes she picks out

another plant, the Wild Radish or the White Mustard. Of course she does not understand her action, but she acts as if she knew that these other plants resembled her cabbage in the one particular of belonging to the same Order, Cruciferæ.

Now, in India we see this instinctive foresight carried a still further step. The caterpillars of many Lycænid butterflies are there continually attended by ants. The caterpillars exude a liquid secretion. The ants love to sip up this liquid. In return for it they protect the caterpillars, even building for them special sheds. In some cases the caterpillars are dependent on the ants, and if taken from the ants will die in a few days.

Now the parent butterfly, when laying her eggs, behaves as if she knew beforehand that her caterpillar will require these ants. Many examples could be given of this. Ants belonging to the genus *Cremastogaster* tend the caterpillars of *Tarucus ananda* and treat them with every sign of attachment. The butterfly seems to know that they will be so treated, for she not only lays on the correct plant, but in addition seeks out those spots on the plant where these ants happen to be. Take again the caterpillars of *Zesius chrysomallus* which I have found in the nests of the Red Tree Ants. Bell tells us that the parent butterfly of this species will never lay her eggs on any tree which does not support a nest of these ants.[1] The fact is that in these and similar instances the correct species of ant is as important to the caterpillar as is the correct species of food plant. How wonderful then is the butterfly's foresight. There is zoological plus botanical knowledge. For the butterfly must select, before she can lay, both the particular species of ant and the particular species of tree.

[1] *Journ. Bombay Nat. Hist. Soc.*, Vol. XXVI, p. 122.

Here is another show of foresight in caterpillars. The caterpillar of the butterfly, *Virachola isocrates*, gets into fruits and penetrates the stones. It works havoc in the pomegranate plantations of India. Now the caterpillar shows a remarkable foresight in keeping the pomegranate attached to the tree while it is engaged in eating the fruit. In the ordinary course of things the pomegranate would fall before the caterpillar had finished its contents. It would rot on the ground : ants would invade it : very soon it would be useless to the caterpillar. Now, the insect behaves as if it knew this. It actually ties the fruit to the branch. From time to time it comes out from the pomegranate, makes connecting ropes of silk which bind the pomegranate on to the branch. It spreads them round the stalk, fixes them to the fruit, also to the surface of the branch. In the end it ties on the fruit so firmly that one has to strain hard at it to drag it off.

The instincts of the solitary wasps supply another good example of foresight. I refer to their plan of attaching an egg to the one spot of particular security. Fabre has given several examples. I will add a few from my own observation.

Ampulex assimilis is a blue wasp which hunts cockroaches in the date groves of Baghdad. When she captures her cockroach she paralyses it with her sting. Then she drags it off to a tunnel, fixes her egg to it, and closes the hole. The egg becomes a wasp-larva which finally eats up the cockroach. Now the wasp acts as if she knew the one safe spot on the cockroach's body to which she should attach her egg. It will not do for her to fix it anywhere, for these cockroaches, after being stung, soon recover, and by their movements would brush off the egg. She always fixes it at one spot, the

outer surface of the femur of the middle leg. This surface is broad and flat. Hence it supplies a good base for anchorage. But when the cockroach moves we see a further purpose. The egg, being fixed to the outer surface of the femur, cannot touch either the leg in front or behind, nor the one on the opposite side. In addition, the edge of the thorax shields it above with a kind of roof. Thus the cockroach can kick about while the egg that will ultimately devour it remains perfectly secure. Hence the prevision of the parent wasp. Although she understands nothing of the act, yet she always finds the one spot where the egg will remain secure.

We go to India for the second illustration. *Sphex lobatus* is another green wasp that deals with her cricket as *Ampulex* does her cockroach. This wasp possesses the same foresight. She fixes her egg across the front of the cricket's breast. The purpose again is the safety of the egg. It is small and delicate. A slight pull or rub will tear it from its hold. Moreover, the cricket soon recovers from the sting which makes things still more dangerous for the egg. Now, the cricket's breast is the one spot where the egg will remain safe. There it is fixed in a recess, anchored to a surface free from movement and protected on either side by the bases of the legs. Also it is sufficiently raised from the ground to escape friction when the cricket moves. In that recess the egg will develop in safety and finally eviscerate its host. Thus again we see the same thing illustrated, the wonderful unthinking foresight of the wasp.

Eumenes conica is a third example. This wasp nests in Indian bungalows. She builds a dome-shaped cell of

mud, and leaves a hole at the summit of the dome. When the dome is finished she pushes her abdomen into the hole and fixes an egg to the top of the dome. Then she fills the cell with caterpillars, and ends by closing the hole.

The step in this procedure of importance here is the instinctive foresight of the wasp in fixing her egg at the top of the dome. The rigidity of the instinct indicates its importance. For when the egg is at the top of the dome it is anchored in a specially safe position and cannot be injured by the caterpillars underneath. The foresight is the same as in the previous examples. The parent wasp fixes her egg at the one safe spot in the cell.

FIG. 2.—*Eumenes conica* putting egg in dome.

But in this example we can go a little further. We can show by a simple experiment how rigid and exact her foresight is. I cut away the top of a cell before the wasp fixes her egg. The breach involves that spot in the dome to which the egg is always attached. What will happen now? The wasp will be unable to satisfy her instinct. For the one spot for attachment is gone. We wait till the time for egg-laying arrives. The wasp comes, puts her abdomen into the cell and brings it to the correct spot. She feels for the surface against which to lay. The surface is gone, so she withdraws her abdomen. She gets very agitated. There is something amiss. Again she tries it. Again failure. She gets more and more impatient, evidently bursting with the impulse to lay. Now we see

the unyielding rigidity of her forethought. There is plenty of space within the dome. She might fix her egg anywhere, to the sides, to the floor. Just the slightest deviation to the right or to the left and the wasp will find plenty of space. But she will not do this on any account. Her instinct permits of no such deviation. It has been ordained that the egg shall be anchored only at the very top of the cell. The wasp makes more efforts, then more withdrawals. A time comes at last when she can wait no longer. She must get rid of her egg. Where does she lay it? Exactly in the place where it should be laid, that is at the very top of the cell. But of course there is nothing to which she can fix it. Hence it is shot into the air and tumbles down to the bottom of the cell. Here we see the instinctive foresight carried to its extreme degree. If the wasp would deviate just a fraction she would find plenty of spots for anchorage. But she stubbornly refuses to make any deviation. Instinctive foresight demands one spot. No other spot is of any account.

One more example will suffice. It has not come under my own observation. But it is so remarkable, so pregnant with foresight, that there can be few more impressive illustrations to be found anywhere in the animal kingdom. I refer to the way Brazilian ants make mushroom gardens and supply them with manure. Dr. Jakob Huber is the authority on this point.[1]

The facts are as follows. *Atta sexdens* inhabits Brazil. It makes a nest deep in the soil underneath the shelter of a large mound. From this nest it constructs well-worn paths to some place where it can collect leaves. The ants go out along these paths, ascend the foliage, cut

[1] *Ants*, by Wheeler, pp. 329–32.

pieces from the leaves, and carry them back into their nest. What do they do with them ? They cut them up into fragments, mould the fragments into sponge-like masses which will serve them as underground gardens. On these gardens they grow a fungus, a small white mushroom-like type of vegetation, on which the ants themselves feed and which they supply to the young ants in the nest. Each species of leaf-cutting ant grows its own particular species of fungus, and none but this particular species is allowed to grow in the nest.

Now these well-established facts are very extraordinary. There is nothing of exaggeration in the statement that these ants manufacture special gardens and grow vegetable substances for food.

But we have not reached the most interesting point. How do the ants first start their garden ? We have seen how they get the suitable soil, from macerated leaves gathered from the trees. But from where do they get the fungi to plant on it ? How does the first bit of mushroom substance find its way into a new nest ?

It occurs in this way. First observe how a nest is started. A queen leaves an established nest, goes off on her marriage flight, meets with a male, becomes impregnated, and starts a new nest on her own. But see what she does before going on her flight. She takes from her nest a large mouthful of fungus, packs it away into a receptacle known as the infra-buccal pocket, and then sets off to find the male. Impregnation over, she starts a nest, digs down into the soil, and shuts herself off from the outside world. Then she commences to start a garden. She spits out her mouthful of fungus, cultivates it by herself, begins to lay eggs and bring up larvæ.

Thus we see how the garden is started. But how does the queen keep her fungi álive ? Obviously they must

have some kind of nourishment. Later her offspring will bring in leaves. But until the offspring have developed how does she manage to keep the fungi alive? Again by another extraordinary act. She keeps manuring them with her own excrement. She frequently takes a tuft of fungus from her garden, holds it in her jaws,

FIG. 3*a*.—*Atta* manuring tuft of fungus with her excrement

FIG. 3*b*.—*Atta* replacing tuft after manuring it.
(Sketched from photographs by J. Huber.)

carries it back to the end of her abdomen, and at the same time shoots out a drop of excrement which she applies to the tuft of fungus. Having done this, she replaces the tuft, using her fore-feet to press it back again into the garden. The performance is repeated once or twice an hour. The fungus absorbs the droplets of excrement and the whole garden gets supplied with manure.

Such a succession of remarkable instincts is, as I have said, pregnant with foresight. It is not necessary to elaborate them further. They are eloquent enough to speak for themselves.

The incidents mentioned in this chapter show how easy it is to be led astray in determining the line between Instinct and Intelligence. How amazingly prudent seem some of these actions! A solitary ant despatches an army in order to retrieve valuable spoil; a butterfly seeks out a special species of ant because later the ant will take care of her caterpillar; a wasp puts her egg in only one spot because it would get damaged anywhere else. How astoundingly clever it all seems! How easy to think that we have here behaviour almost on a par with human intelligence! But such an idea is quite without foundation. These actions do not imply intelligence. They have the outward appearance of intelligence, but they have not been performed with intelligent motives.

Take the butterfly that lays amongst ants, for example. The butterfly does not know why she seeks out the ants. Her egg is just something that she must get rid of. It is a thing that never interests her hereafter. Neither her egg nor her caterpillar will she ever see or think about again. She cannot even have the idea that caterpillars have anything to do with her life. Why then this wonderful forethought for its welfare? Why seek out a particular ant to care for a progeny she knows nothing about? Is that the knowledge we call Intelligence? No; it is something altogether different. It is the knowledge we call Instinct. It is a knowledge born with the butterfly, as much an inherited part of her nature as are her legs and wings. Every butterfly in the species

has it. They all seek out the particular ant just because they were born to do what all their ancestors had done before them. They must do it, though they know neither how nor why. They must obey the inherited impulse. The wasp that fixed her egg at the top of the cell shows how powerful is this word *must*. She *must* put her egg at the top of the cell. She knows no more why her egg must go there than does the butterfly why she puts it with the ants. Yet we have seen that it *must* go there. Take away that particular spot and the wasp is at a complete loss. She cannot fix her egg anywhere else.

We must not, therefore, be led astray. These acts, though apparently so wonderfully prudent, are in reality thoughtless and blind. The knowledge behind them is quite unconscious. It is a learning that has never been learned, an impulse that must be obeyed.

Yet see to what remarkable perfection this blind unconscious impulse can attain.

CHAPTER III

The Inflexibility of Instinct

Instinct in its action is utterly remorseless. The end in view must be secured at all costs. Every impediment must be overcome. Perhaps the most curious instance of this is the one which interested Darwin. He remarks on the fact that the migrating instinct will sometimes conquer even the maternal instinct. Late in the autumn swallows and swifts have been known to desert their young and leave them to perish miserably in the nest. How intense must be the impulse behind the performance of so unnatural an act!

My examples will come into four categories.

1. The Migratory Instinct

A swarm of locusts, when invading a territory, advances with irresistible force. Nothing can check it. Every obstacle must be overcome.

I once met with an immense swarm marching towards the river Euphrates.[1] It was a march of hoppers, half-grown forms, that jumped and crept along the desert sand. There were millions and millions of them. They covered hundreds of square miles of desert. In places they clothed the sand so densely that it looked like a green lawn. All advanced steadily, orderly, persistently, forcing their way across every obstacle and keeping a fixed

[1] *Nature at the Desert's Edge*, p. 291.

direction to the North. Nothing deflected them. They pushed steadily northward. What would happen if by any chance they came up against an absolutely unsurmountable barrier ? Such an occurrence, should it arise, would give us a test of the instinctive force.

An excellent opportunity does arise. The Euphrates river, in full flood, stood right across their course. The river was vast, several miles in width, due to the water having overflowed its banks. A sea confronts the advancing army. They can no longer continue northward. Either they must turn or be destroyed. What do they do ? They go straight for the river. Rather than turn they accept destruction. The army marches out into the sea. The leaders go forward, the van follows, myriads upon myriads spread themselves upon the waters. A vast swarm of drowning insects is swept downward on the flooded stream. Here we see the inflexibility of instinct. The swarm is imbued with the instinct of direction. It must go northward. Nothing else will satisfy it. Rather than swerve from that predestined course myriads upon myriads will be destroyed.

My Euphrates observation is not the only one available. Mrs. Barber saw something similar in South Africa.[1] A swarm of hoppers reached the Vaal River, which, like the Euphrates, was then in flood. They made some attempt to find a place to cross. But, finding none, they at last took the plunge. Vast multitudes essayed the passage. The current favoured them. Sedges and water-plants gave some of them a foothold. By the help of these many got across, but numbers were washed away and drowned in the flooded stream.

The same inflexibility drives the full-grown swarms across wide arms of the ocean. I have seen them crossing the Persian Gulf, travelling both by day and night.

[1] *Cambridge Natural History*, Insects, Part I, p. 295.

Also I have met them in the Red Sea far out of sight of land. Often the same destruction waits them as takes place during the hopping stage. A sailing ship in the Red Sea fell in with an amazing scene of carnage. For five days the ship was amongst flying locusts. Her decks became inches thick with their corpses. The waves were white with them as though covered with snow. On the shore they formed banks 3 feet high which extended several miles along the coast. Such is the result of undeviating instinct operating on immense hordes.[1]

The migrations of butterflies display the same inflexibility. This phenomenon has been noticed all over the world. Streams of butterflies, for many days in succession, flow persistently in one direction. Day after day the direction is the same. Seldom if ever do any return. Usually they fly quite close to the ground. As with the locusts, nothing will deflect them. Houses appear; the butterflies get round them. Woods are met with; the butterflies thread their way through the trees. A range of mountains stands across their path: the butterflies ascend, perhaps 5,000 or 6,000 feet, and descend on the other side. Often great swarms, like driving snow, push relentlessly out to sea. Such swarms may traverse wide arms of the ocean. Clouds of them sometimes visit the Bermudas, 600 miles from the nearest coast.

Here is a striking instance that I met with, a multitudinous flight of butterflies faced by the greatest barrier on earth. The barrier was the Himalaya. This is certainly an excellent occasion to judge the force of instinct. The flight was observed at Dharmsala in the Dhauladhar range of the Himalaya. It commenced at

[1] Quoted by Miss Cheesman in *The Great Little Insect*, p. 67.

the end of March. Then a few butterflies began to appear. They were of the Large White species, *Pieris brassicæ*, and I noticed that the few which were then abroad all moved up the slope of the range. At that time the number was so few that I could count only thirty-seven butterflies flying past me in fifteen minutes. All, however, were going north-west; and all steadily up the slope. There was no hesitation, no deviation; all struggled up the face of the range. During subsequent days the flow increased. I kept watch on it from my station at 6,000 feet. By mid-April the stream had become dense. The butterflies then passed in hundreds a minute. White Pierids remained the most abundant, but other representatives were *Colias fieldi*, *Vanessa cashmirensis*, and here and there an occasional Blue. For two months the stream continued. What millions and millions of these fragile migrants must have struggled up that mountain range! Where were they going? What was their object? The height of the range was 17,000 feet. Beyond and behind it were far loftier ranges, an impassable barrier of rock and ice, standing right across their course. What inflexibility of instinct to force them up this obstacle! How intense must be the driving power? In my efforts to find out the purpose of this flow, I followed it up to the snow-line, which then lay at 10,000 feet. There the stream still continued, thinner certainly, but still the same stream, pushing outward on to the snow. Where were they making for? Above them was nothing but ice and rock; beyond them still more massive ranges. Yet every day thousands ascended to that waste where of course they were irretrievably lost. Here again we have the force of instinct. Myriads of butterflies get themselves destroyed rather than turn from the predestined course.

Dragon-flies supply still further examples. We have

that remarkable observation by Hudson.[1] He calls them dragon-fly storms. It seemed to be a regular occurrence in La Plata. The swarms came before the violent wind, not with the wind, but distinctly in advance of it. They swept by with a flash, going at 70 to 80 miles an hour. All travelled to the North-East, and of the countless millions that comprised a storm not one ever returned.

I have never observed a migration of caterpillars, yet we know that they advance with undeviating force. Imagine an army of these crawling ravagers 85 miles broad and 30 miles in depth! They meet with a gully. It does not deflect them. Myriads fall in, choke it to the top with their dead bodies, while those that follow climb over the dead. Any that happen to halt or hesitate get submerged by the army that pours over them from behind. How ridiculous it sounds to speak of a railway train brought to a halt by a horde of caterpillars! Yet such an incident has happened in New Zealand. By crushing them in thousands the wheels have got so greasy that the engine could no longer grip the rails. All were marching across the track, driven, like the locusts, the butterflies, the dragon-flies, by a blind inflexible force.

2. Perforators and Borers

The impulse to perforate through every obstruction again shows how inflexible is instinct.

We get good examples from the Ichneumon wasps which drive their ovipositors into the trunks of trees. The instrument looks like a delicate thread, yet we see it, by dint of the utmost patience, go deep into solid wood. Here is what I have several times seen in India. Wasps belonging to the genus *Syzeuctus* were in the habit of perforating trees in my garden. Their purpose was

[1] *The Naturalist in La Plata*, p. 132.

to lodge their eggs in a grub buried in the substance of the wood. What patience and determination lies behind this instinct! The wasp finds a spot, fixes herself to the bark. With legs spread out to make a broad base, she brings her ovipositor perpendicularly against the bark. Then comes the pressing, the rocking, the screwing. It is an amazing operation. The wasp is driving a slender thread through an inch of solid wood. Mechanically it looks utterly impossible. How can a thread escape bending or fracturing against the unyielding wood. What would man do if faced with a similar problem? He would frankly admit its utter impossibility. Yet the wasp manages to get her thread in. The hair enters. Infinitely slowly the penetration advances: after half an hour it is only half way in. The delicate screwing and twisting continues. In three-quarters of an hour it is down to the hilt. Then comes the laying of the egg, probably in the body of some beetle grub that the wasp knows to be buried in the tree. How is this remarkable act effected? I can give no explanation. The spectacle is an amazing one. It beats me how that slender hair goes an inch into the trunk of the tree. All I see is the inflexible act of instinct. Nothing can exceed the infinite patience which the wasp applies to this delicate drill.

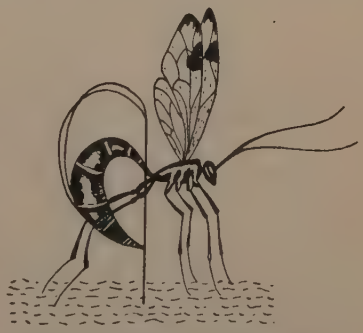

FIG. 4.—Ichneumon wasp perforating tree trunk.

So much for a perforator. Now for some borers. The

larva of the Wolf Moth, which is allied to the clothes-moth, burrows in hard wood. Nothing will stop it. It bores through everything. A deal plank is an obstacle of no importance: onward it goes through the thickest beams, and even through the hardest knots.

There is an excellent example in the British Museum of the inflexibility behind this instinct to bore. This is an instance of a wood-wasp penetrating solid lead.[1] The females of these wasps have powerful ovipositors which project from the tail like a long spear. The instrument is used for perforating wood, and by means of it the wasp implants her egg in the substance of coniferous trees. The egg develops inside the tree, changes to a grub which tunnels through the wood, and may have to bore a considerable distance before reaching the open air.

Now a piece of pine wood was cut in France and found its way to the British Museum. The wood was cut for industrial purposes. It was first shaped into a cylindrical spar, and then surrounded with a casing of lead. The casing consisted of fifteen layers. Each layer was one-tenth of an inch in thickness. Therefore the total thickness of the casing was $1\frac{1}{2}$ inches of solid lead. But the wood, previous to its being encased, had happened to be infected by one of these wood-wasps belonging to the species *Sirex cyaneus*. Eggs had been laid in the substance of the timber; and the time came for the young wasps to emerge. They tunnelled through the wood, reached the surface, and came up against the casing of lead. Then what happened? The wasps refused to be deflected by the metal. On the contrary they attacked it vigorously with their jaws. They actually gnawed through layer after layer. Some of them died at stages in the journey, but others succeeded in getting

[1] The Exhibit is described by Dr. Waterston in *The Natural History Magazine*, Vol. I, No. 2.

right through the 1½ inches of solid lead. It is difficult to know which is the more wonderful: the incredible strength of these small creatures, or the pertinacity which drives them to their ends.

3. Some Numerical Estimations

It is possible by simple mathematical calculation to give some impression of the inflexibility of instinct.

No instinct is more wonderful or involves more perfection than that of a spider building her web. The measuring of distances, the calculating of angles, the drawing of threads parallel to one another, in fact all the intricate geometry of construction makes it one of the most wonderful of instinctive acts. At least it is one which a reflecting mind can look on only with the greatest admiration. Here is a measure of the persistency involved in it. The web in question is 22 inches in diameter. How much work does the spider do from the commencement to the completion of that web? Once I measured it with fair accuracy.[1] The species of spider was *Araneus nauticus*, and the web was being spun across a Himalayan pool. The spider, in weaving her 22-inch web, emitted 122 feet of thread, made 699 attachments, and travelled over a distance of 178 feet. Yet the whole work occupied the spider only thirty-six minutes.

I give another example from spiders. These creatures, when spreading their cartwheel snares, lay out, as is well known a number of spokes that all radiate from the hub of the wheel. Now, if the spider is spoke-making, what will she do if I cut the spokes? In other words, how strong is her spoke-making instinct? Will she go on making spokes if I cut them as fast as she makes them? I try the experiment. When the spider makes a spoke

[1] *A Naturalist in Himalaya*, p. 117.

I cut it.[1] She goes on making; I go on cutting. We keep pace with and pit ourselves against one another. I cut the spoke twenty-five times, and twenty-five times the spider replaces it. The spider then refuses to make any more. Though she tires of the business before I do, yet we see how persistent her instinct is.

Some good examples can be quoted from Fabre. Take, for instance, the Leaf-Cutting Bee, *Megachile sericans*.[2] This insect makes her nest with pieces of leaves, some cut into circles, others into ovals. She is a solitary insect, and works alone. How much labour is involved in her nest-making? Fabre amused himself with this simple problem. By counting the pieces of leaves in a nest he calculated the number of the bee's journeys. They amounted to 1,064!

The Mason-Bees supplied him with another record. The French species, *Chalicodoma muraria*, used to build her nest on large pebbles.[3] Fifteen cells composed a nest. All the cells were built of mud, carried by the bee in individual pellets. What is the measure of this nest-building instinct? Can we find out how much work has been involved? Fabre made an attempt to measure it. He tells us that the successive comings and goings involved the bee in a distance of 275 miles, about half-way across France from North to South!

Other impressive examples could be given. The Peckhams, for instance, watched a bee which worked ceaselessly day and night for a period of forty-two consecutive hours! Fraser met with ants engaged in stealing grain. He collected what they had accumulated. It weighed 240 lb.! The sportsmen of a certain town in the United States established for themselves a shooting-range. Many

[1] *A Naturalist in Himalaya*, p. 95.
[2] *Bramble-Bees and Others*, p. 273.
[3] *The Mason-Bees*, p. 261

mound-building ants frequented the spot, and the spent shot used to fall amongst their mounds. The ants were in the habit of collecting pebbles which they needed for the business of mound-construction. But soon they began to collect shot. And with such assiduity that when the matter was investigated more than 50 lb. of shot was extracted from their mounds! Finally we have an observation from Marshall. He saw an Ichneumon Fly, one quite unadapted to aquatic life, remain under water for twelve hours in order to lay her eggs in the larvæ of dragon-flies! How intense is the force of instinct when we find these comparatively insignificant creatures performing such stupendous feats.

4. Experimental Illustrations

A common feature all through Nature is the well-known principle of harmonization. Numerous animals, particularly insects, escape enemies by this simple plan. An opportunity once came to me to realize how intense may be the instinct that lies behind this particular device. My example comes from Central India. A Clubionid spider, long and slender, used to lie full length along a stalk of grass. It was exactly the same colour as a straw, and was all but invisible when aligned along the stalk. Now the spider behaved as if it understood that its safety depended on harmonization. It refused to move from its place upon the stalk. I met with one imperturbable example. I pushed it with a straw, I pressed it, I pinched it; but it absolutely declined to move. I stuck a pin into it; I snipped off a leg: still the spider refused to budge. Nothing would rouse it. Its one impulse was to remain fixed. By blending with the stalk it might escape the enemy; if it moved, it felt itself lost. Therefore it stuck inflexibly to its post. Not

till I had almost cut it in half did it break from the instinctive force.

The incident reminds us of those foxes on the Pampas which so exactly simulate death. Hudson tells us that *Canis azaræ* shams death with the utmost perfection. Moreover, scarcely anything will force it from its simulation. Hudson saw the animal lashed with a whip without producing the slightest effect. The Gauchos practised on it barbarous experiments without being able to force it into life.

I pass to an experiment on a mason-wasp. It shows the same thing in a different way, the intensity of the instinctive force. The species in question is *Eumenes conica*. It builds vase-shaped cells of mud on the walls of Indian bungalows. In the cell it lays an egg, fills it with caterpillars, then seals it with a lid of mud. This is the experiment. Camphor is a substance these wasps detest. The smell of it is loathsome to them. They hate to come near it. What, therefore, will the insect do if, when she is building, I put some camphor in her cell. This will test the inflexibility of her instinct. For instinct will compel her to go on with the building; the loathsome camphor will drive her away.

The cell I experiment on is half built. The wasp is coming and going with mud. In her absence I place a lump of camphor in her cell. On her return she is instantly aware of it. The smell arrests her when an inch from the cell. She approaches warily, reaches the wall and tries to apply her clay. But the odour overcomes her. She retreats before the fumes. Nevertheless, she again and still again approaches. I see her do so a dozen times, until in the end she makes a splendid effort. Her head goes down almost on to the camphor and she

rapidly moulds her bit of mud to the wall. The inflexibility of instinct conquers: it overcomes the olfactory sense. But this is not all. The wasp returns again and again; each time she brings more mud for the wall; each time faces the stupefying fumes; in the end she completes her pot. She even puts her egg in it, fills it

FIG. 5.—*Eumenes conica* recoiling before camphor in half-built cell.

with the usual ration of caterpillars and finally seals it with a lid. Of course, the labour is utterly useless, for nothing could develop in so foul a cell. However, it illustrates the point in question, the inflexibility of the instinctive force. The wasp, at all costs, usefully or uselessly, must fulfil the predestined instinct to build.

The Peckhams mention a charming observation which

exemplifies the same point.[1] *Pompilus biguttatus* is an American wasp which spends her life chasing spiders. Having got a victim she immediately paralyses it, then drags it backward to a nest. This backward-dragging habit is the point to notice. It is of course necessary with a large spider. By no other method could she get it to the nest. But the Peckhams met with one of these wasps which had happened to get hold of a very small spider. In this case there was no need to drag it backward. The wasp could just lift it in the ordinary way and march forward with it towards the nest. But see how she behaved. It shows how strong is the backward-dragging instinct. Although she could go forward, yet she persisted in going backward, nevertheless she felt a constant desire to go forward. She behaved as if drawn in opposite directions, which resulted in a kind of waltzing movement, a succession of circles on the sand which much amused the observers who watched it.

Then we find other impressive illustrations amongst the ants and social wasps. There are those simple experiments of Lord Avebury.[2] He took an ant that was carrying larvæ to her nest, imprisoned her for a week, then released her, putting her back again to her work. What did the ant do? Though she had been confined for six days, yet she resumed her old task immediately. She picked up a larva, carried it to the nest, then returned in half an hour to obtain a second load!

One of his wasps had got smeared with syrup. With the object of washing her he put her in a bottle half full of water.[3] He shook her up in it till the syrup was removed. Then he transferred her to another bottle and put her to dry in the sun. When she had recovered he

[1] *Wasps, Social and Solitary*, p. 300.
[2] *Ants, Bees and Wasps*, p. 28.
[3] *Ibid.*, p. 314.

let her out, never expecting to see her again. Yet what was his surprise when in thirteen minutes she was back at the syrup and continued to visit it all the afternoon!

Instinct clearly needs something tremendous to deflect it from its ordained course.

CHAPTER IV

THE RHYTHM OF INSTINCT

Instinct frequently reminds us of a chain. It often consists of a series of actions bound together like so many links. All these actions are connected in series. They form an interdependent sequence. Each is caused by the one that precedes it and is the cause of the one that follows.

The reproductive activities of Mason-wasps possess a fourfold rhythm. There are four links in their chain of action. *Eumenes conica* shows this clearly. First, she builds a cell; second, she lays an egg inside it; third, she stuffs the cell with caterpillars; fourth, she closes the cell with a lid. Building, egg-laying, provisioning, closing; these are the four links in her instinctive chain.

Now the wasp in the ordinary course of events follows that unchanging rhythm. Her actions form a chain of events, of which each link must follow another according to a predestined plan. The completion of each event seems to act as an impulse for the commencement of the next one. The completion of building gives the impulse for egg-laying, the completion of egg-laying gives the impulse for provisioning, the completion of provisioning supplies the impulse to close the nest with a lid.

That being so, it is interesting to observe the degree to which instinct is controlled by rhythm. Must events follow in that definite sequence? Does each link in the chain depend on the preceding link, and is its fulfilment

strictly necessary for the development of the link that follows ? Without going so far as to reply in the affirmative, we shall make it clear in this chapter that the rhythm of instinct is tremendously strong.

Examples from Mason-Wasps

Our best way of observing the force of rhythm is to do something to alter that rhythm and then see how the animal behaves. Take *Eumenes conica* and her fourfold rhythm. We shall test her with a few experiments.

Experiment 1

Eumenes conica has built her cell. She has laid an egg in it and is collecting caterpillars. In other words, she is engaged at the third stage of her fourfold rhythm. While she is absent looking for a caterpillar I cut away the upper margin of her cell. She returns. It happens to be only a visit of inspection. For some reason she has failed to find a caterpillar. However, she commences to look to her cell. It is clear that she knows that the cell has been tampered with. She investigates it carefully. Her antennæ play around the cut-away margin. She remains for a long time testing it. One cannot but believe that she knows the nature of the damage that has happened to her cell. Then she goes off. I expect to see her bring a pellet of mud and make good the damage which she certainly observed. A wrong anticipation. Her burden is a caterpillar, not a pellet. She brings more and more of them, stuffs the cell full of them, finally closes down the cell with its upper margin still cut off.

Now, why did the wasp behave so foolishly ? Why did she not re-build the margin which I had cut away ?

It is not because she cannot re-build. I have often seen her repair a hole. It is because she must fulfil her rhythm. She happens to be at the provisioning stage when the problem of building is presented to her. Her business is to provision, not to build. She must stick to the business in hand. Instinct impels her to go on with her rhythm. She must keep provisioning just because she is provisioning. She is engaged at number three stage; hence she will not go back to number one.

Experiment 2

Here is a confirmation of the previous experiment. She is collecting caterpillars. This time I cut a square piece of mud from the wall at the edge of the gate. The opening into her cell is doubled. Its shape is completely changed. Again, though she sees it, she cannot repair it. All she does is to bring caterpillar after caterpillar. At length provisioning finishes. Now we come to the fourth stage. The wasp brings mud and closes the gate. But she closes not only the gate, she also fills in the square hole. How is it that she re-builds now? Because closing is really only building. The fourth stage in the rhythm is an act of plastering; hence at the fourth stage she can fill the square hole.

Again we see the force of rhythm. The wasp has a certain course laid out for her. She must keep to the occupation that engages her at the moment; she will not change her psychological routine.

Fabre gives a very interesting example. *Chalicodoma muraria*, when provisioning her cell, goes through a kind of double act.[1] First she dives her head into the cell

[1] *The Mason-Bees*, p. 74.

in order to disgorge the contents of her crop. Then she comes out and goes in backward to brush from her abdomen a load of pollen. At the moment when she was about to go in tail-first Fabre brushed her aside with a straw. Her second act was thus prevented. What did the bee do? Begin the whole performance over again. She dived in head-first, though she had nothing in her crop to disgorge; then she made another attempt to carry out the tail-first part of the act. Fabre again pushed her aside. Again she repeated the whole performance. And this went on just as long as the observer pleased to do it. Thus the bee behaved like a machine. Her storing operation had a twofold rhythm, a tail-first act following a head-first act. And we see that the bee must follow this rhythm. She cannot perform the tail-first part of it until the head-first part has been done.

Examples from Hunting-Wasps

Turn now to the hunting-wasps. We again see a stern obedience to rhythm. *Psammophila tydei* hunts caterpillars in the Himalaya. Her instinct possesses the following links: She finds a caterpillar, paralyses it by stinging, drags it to a tunnel, lays an egg on it, finally closes the hole. Let us cut out the first two links. I take a caterpillar from a wasp's nest, one that has already been paralysed and lies helpless as if it were dead. I give it to another wasp which is hunting about for prey. This is a valuable find for the wasp. She now has a victim already helpless. She need not waste her time or poison in stinging it. All she need do is drag it away. But the wasp could not recognize these advantages. She seized hold of the helpless caterpillar, pierced it with her sting in the orthodox manner eight successive times. Then she proceeded according to routine to crush her

victim's head. Of course all such labour was useless. The stinging and crushing had already been done. That the caterpillar was helpless and made no resistance did not seem to matter to the wasp. She could not take advantage of what others had done for her. She had found a caterpillar, therefore she must sting it. That is the routine of her particular instinct. The paralysed must be again paralysed, the crushed head must be again crushed, before the next psychic step can follow, that is the dragging of the victim to the nest.

I give another instance from my own experience. *Sphex lobatus*, an Indian huntress of crickets, has the following strict routine. She digs into a cricket's den, drives the cricket out into the open, pursues it, paralyses it, drags it off. She then incarcerates the cricket in the cricket's own den, lays an egg on it and closes the hole.

I find one of these wasps searching for crickets. I have with me the very species she victimizes and I throw it before her on the ground. I expect to see her attack it instantly. This is the very thing she is searching for. She can have it without the labour of further hunting and the toil of digging it out of the ground. She sees it immediately; her antennæ tremble; she rocks from side to side. She makes a little run at it, and every moment I expect to see her sting. But no! For some reason she refuses to touch it. The cricket runs off, she follows it a little way, then gives up all interest in it and goes off to search for another. Clearly she will not have my cricket; she is determined to find one for herself.

I repeat the experiment and get the same result. The wasp sees and recognizes the cricket, but obstinately refuses to attack it. I try her again and again: always

the same result. There is no doubt that she eagerly wants it. For I wait till she is actually digging for a victim. When she is so engaged I put the bait before her. Still she will not attack.

Why this unexpected behaviour? If she takes what I offer her she will be saved hours of strenuous toil. It is another instance of rhythmic bondage. Ordinarily she must follow a definite routine. She must first dig, then expel the cricket, then paralyse it with a sting. Excavation, expulsion, stinging; these are the links in her instinctive chain. I offer her the third of these links. But she cannot take it till the others have been satisfied. To do so would break the instinctive rhythm, which the wasp finds an impossible feat.

Those delightful observations recorded by the Peckhams mention a somewhat similar case.[1] *Pompilus quinquenotatus* paralyses spiders. The Peckhams wished to see the act of stinging. They took advantage of the wasp's habit of placing her victim temporarily on a plant while she runs into the nest to see that all is well. During the absence of the wasp in the nest the Peckhams exchanged her paralysed spider with an unparalysed one of the same species. They expected that the wasp, on her return, would sting it. But the wasp refused. She clearly knew that this was a vigorous spider and not the helpless thing that she had temporarily abandoned. But she absolutely refused to touch it. She went off to hunt for another in the woods. Again we have the same explanation. These victims must be hunted down before the act of stinging can be done. Hunting is link number one in the chain. That link must be completed before link number two can be reached.

[1] *Wasps, Social and Solitary*, pp. 207, 208.

I am tempted to give a second illustration from the Peckhams.[1] *Pompilus biguttatus* is another spider-huntress. When she gets her victim she drags it to the nest, but, when doing so, she has the interesting habit of climbing to the top of any obstacle she meets with and making a downward flight towards the nest. This manœuvre helps her transportation of the spider, for each flight carries her a fair distance, and farther than she could have got her victim on the ground. But the Peckhams quote a particular instance which shows how strong is the rhythm of this act. They saw one comical individual that carried the plan to the extreme of folly. Not only did she climb up the obstacles in her path, but if she saw, so to speak, out of the corner of her eye, a stone or a plant 3 or 4 inches to one side, the sight of it called her to climb and climb it she did, though in order to do so she had to leave her path. The Peckhams compared her to Dr. Johnson, who had to obey the rhythmical impulse to touch every tree or post that he met with along the road.

It is the habit of many species of *Sphex* to go through a peculiar ceremony before dragging their crickets into their burrows.[2] They do not just pull them straight in. Their ritual is to leave them close to the entrance, then run inside the burrow, then come out and pull the cricket in. The three stages always take place: the leaving at the entrance, the domiciliary visit, the final dragging in. This little ritual gave Fabre an opportunity to play a trick on *Sphex flavipennis*. He interfered with link one in the chain. The *Sphex* had left her cricket near the entrance and was making her domiciliary visit. Fabre

[1] *Wasps, Social and Solitary*, p. 300.
[2] *The Hunting-Wasps*, p. 72.

pulled the cricket a few inches from the hole. The *Sphex* came out, her intention being to drag in the cricket. Not finding her cricket where she expected, she had to make a search before she came on it. What did she do then? Not what she came out with the intention of doing. She dragged the cricket back to its place near the entrance and went into the hole alone. Fabre repeated the trick. Again the *Sphex* came out. Again the same manœuvre. The cricket is brought back to the correct place. Fabre repeated it forty times and the wasp always dragged the cricket back. All wasps did not act with the same pertinacity. Yet the incident shows us how strong is rhythm. The leaving of the cricket close to the entrance is the first link in the instinctive chain. This link must be completed for the instinct to follow its normal course.

That the sight of an object can start a rhythm has been demonstrated in the clearest way by Ferton, the excellent French observer of Hymenoptera.

Ammophila holosericea, a chaser of caterpillars, had provisioned a cell at the bottom of a tunnel.[1] She had laid an egg in it and had filled in the tunnel with sand. When she was finishing Ferton placed close to her nest another caterpillar previously paralysed. The wasp found it. The sight of it gave the first impulse. She felt she must bury it. Hence she commenced to re-open the hole. She got down into the tunnel, found the cell full. The sight of the full cell gave a second impulse. She commenced closing the tunnel once more. Having completed this, she again happened to come across the caterpillar. A third impulse. Back she went to the nest

[1] *Annales de la Société Entomologique de France*, Vol. LXX, p. 142.

and began re-opening it again. She reached the bottom. A fourth impulse. She commenced to close it once more and this time finished the job. Thus we see how hopelessly is the wasp confused. The sight of a caterpillar gives the impulse to provision, but provisioning has just been finished, and the finishing of provisioning gives the impulse to close. Thus she is driven to both opening and closing, and fooled between the two acts. It illustrates the force of rhythm and the confusion that necessarily follows when we alter its normal course.

Examples from Beetles

Dung-Beetles show a very rhythmical behaviour. I refer particularly to *Gymnopleurus miliaris*. Its instinct is briefly as follows: A pair of beetles finds a pad of dung. From the pad they shape a ball. They roll the ball along the ground and bury it at some convenient spot. Along with the ball they inter themselves, and at leisure devour the mass. Finding, shaping, rolling, burying; these are the links in their instinctive chain.

Take them first at the rolling stage. I rob a pair of their spherical ball. I give them another ball exactly similar. They accept it, apparently do not notice the difference, and continue to roll it along. Nothing I have done has altered their rhythm. All I do is make an exchange. Hence everything goes on as before.

Now let us try to alter the rhythm. Two beetles have found a pad of dung.[1] They are just about to join forces, dig into it and shape a ball. I give them one already made. This is a distinct gain to the pair. They are saved the work of digging and moulding. All they need do now is accept the ball and roll it off to the nest. But they do not appreciate my gift. They turn away from

[1] *A Naturalist in Hindustan*, pp. 262–4.

it and go back to the pad. I try the same with others, sometimes single beetles, sometimes pairs. Not one will accept my balls. At the rolling stage they always accept them; at the shaping stage they stubbornly refuse. Why? I need not labour the explanation. When the beetle is shaping she is shaping; she has not the instinct to do anything else.

I try then the converse experiment. Two beetles have shaped a ball and are busy rolling it away. I take them from it and return them to the pad. They realize the loss, get very perturbed. They wander everywhere searching for their ball. If by chance they find it or another ball like it their instinct is satisfied and the roll is resumed. If they fail to find it they just search and search, and in the end fly away. One thing they never do is commence making a new ball. It is not for want of example. There are other beetles working on the pad, some digging, some shaping, others starting on the roll. The two searchers run about in the midst of them, but are quite unable to imitate their toil. Give them a ball and they immediately accept it. But they cannot make a second for themselves. They were at the rolling stage when I took them from the ball. Instinct cannot go back on its rhythm. When rolling, they are filled with the impulse of rolling. Hence they cannot make a ball.

Examples from Spiders

No instinct is more full of rhythm than that of a spider making its snare. Nor does any creature obey more implicitly the claims which rhythm demands. I must make a few brief remarks on the snare. Then my experiments will be understood.

The species I refer to is *Araneus nauticus*. The spider begins by constructing a framework. That shown in

the sketch is triangular, the very simplest type. Within this framework it spreads out radii, like spokes diverging from a central point. Its next act is to wind a hub round the centre, five or six turns of a close-wound thread. Then it proceeds to make a series of bridges. These consist of another spiral wound three or four times round the snare and attached to all the spokes. Having finished its bridges, the spider proceeds to make its viscid spiral. This is a long and tedious act. The spider goes out to a point near the framework. From there it commences another spiral which it winds round and round the snare, gradually working in towards the centre and attaching the spiral to every spoke. This spiral is made with admirable perfection. All its turns are mathematically parallel. As every one knows who has looked at a web, it is beautifully and geometrically exact. There is one point in the work that I wish to lay stress on. The spider, when laying its viscid spiral, uses its circle of bridges to cross over from radius to radius. It cannot stretch across from radius to radius. The making of the bridges, therefore, is a very important link which must precede the laying of the spiral.

Observe the five links in the chain of construction: (1) The Framework, (2) The Radii, (3) The Hub, (4) The Bridges, (5) The Viscid Spiral.

Now let us proceed to experiment. We will concentrate on link number 4. What will happen if I cut a bridge when the spider is laying its spiral? Remember that the bridge is being used for the purpose of getting from spoke to spoke. I snip one across, one of the bridges in the outer circle (Fig. 6). The spider continues. It comes round to the broken bridge. It shows some hesitation. The cutting of the bridge causes it some difficulty. Its remedy is clear. All it need do is run another thread across and manufacture a new bridge. But it

never thinks of that. Having lost its bridge on the outer circle, it crosses over by the bridge on the circle next inside. In spite of my interference it carries on as well as it can.

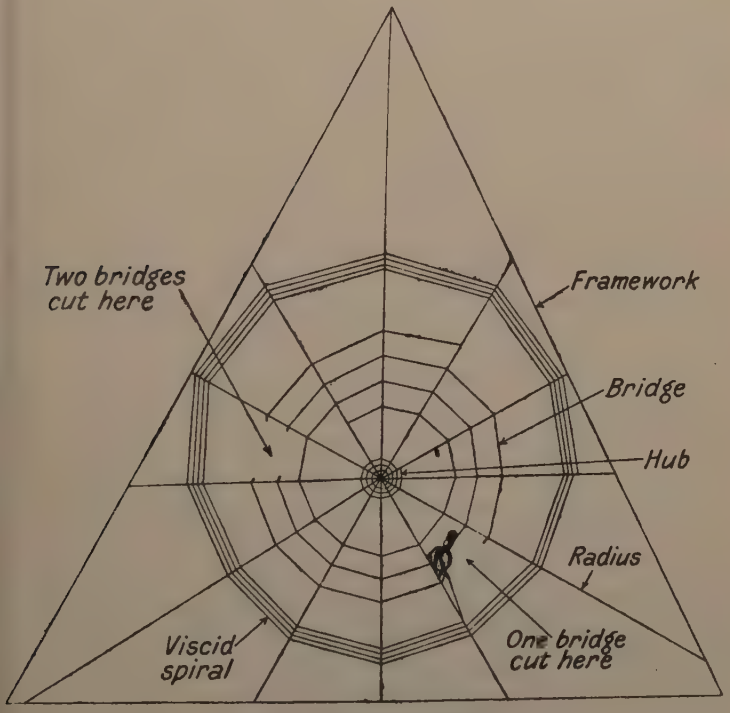

FIG. 6.—Circular Snare.

Showing how, after a bridge is cut, the spider cannot remake it, but crosses over by another bridge.

I turn to another segment of the snare. There I cut two bridges (Fig. 6). I have doubled the difficulty before the spider. The result is the same. The spider now crosses by the innermost bridge. I divide all the bridges in a segment. The spider must now go right into the

centre before it can cross from radius to radius. It has to make three times as long a journey and pay out three times as much line in order to complete its spiral in that segment. Yet in spite of its longer journey, its labour, its confusion, the spider works mechanically on. A single thread would make a bridge. The act would not occupy the spider a second. It made many bridges a few moments ago ; why cannot it make a bridge now ? All it can do is stick to its spiral and adapt itself as well as it can to the difficulties put in its path. One thing it cannot do is go back on its rhythm. Bridge-building is a link that precedes spiral-making. So the spider cannot make a bridge now.

I made many experiments of a similar type. But one more will make my point quite clear.[1] My sketch (Fig. 7) shows a snare with twelve radii. In this snare I cut all the bridges, that is thirty-eight separate threads. In the sketch the cut ends of the bridges are seen still attached to the spokes. The spider has now not a single bridge. In order to cross from radius to radius it must either build new bridges or else climb in to the centre of the snare at every successive turn of its spiral. This is a tremendous obstacle to the spider. Not only must it make much longer journeys, but the loss of its bridges has weakened its snare. The spokes are slack, having nothing to brace them. They wave and tremble in the air. If the spider can possibly go back on its rhythm it must attempt it now.

At first it is alarmed by my experimentings. Soon, however, it returns to its task, the laying of the viscid spiral. Now observe the hopelessness of what it does. Of course, it meets with immediate trouble. It can find no bridge. Though much confused and surrounded with difficulties, nevertheless it sticks to its task. Each time

[1] *A Naturalist in Himalaya*, p. 131.

it crosses from radius to radius it has to travel in to the centre except where the radii are so slack that it can manage to step across. This results in great architectural disorder. The slack radii confuse its sense of ten-

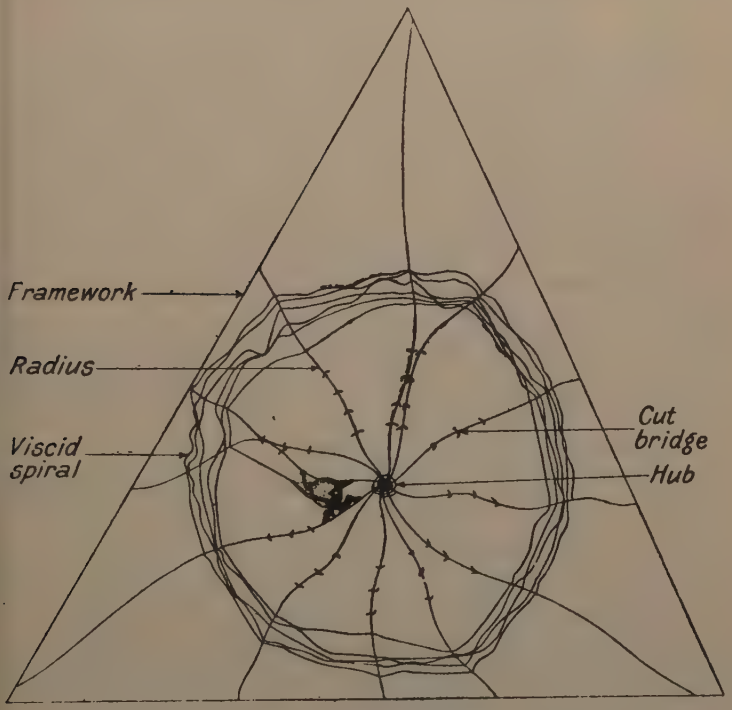

FIG. 7.—Circular Snare.

Showing how, after all the bridges are cut, the spider cannot remake any of them, yet persists in building its snare.

sion and at every turn it finds itself perplexed. It is all the time fixing its thread incorrectly. Radii manage to get glued to radii. Symmetry and parallelism get completely lost. Nevertheless construction continues, though

the snare rapidly becomes a tangle. The spider, however, seems quite satisfied. It still makes no effort to place new bridges. It just sticks to the monotonous routine. A few bridges would solve its difficulties. A thread or two here and there would save the snare from a hopeless tangle. But this is quite beyond the spider. It would demand a change in rhythm. The spider would have to make bridges at a time when its instinct is to make viscid spirals. It would have to go back on its rhythmical sequence, which, as we have seen, is beyond its powers. Hence it just carries on blindly and hopelessly. On it goes, round and round, groping with its forelegs for something to guide it, and always fixing threads in the wrong place. At every turn its difficulties increase. More and more confusion follows in its architecture. Nevertheless it sticks to its duty, the manufacture of its viscid spiral. At length it ceases ; its business done. It has spread its spiral, or at least the tangle intended to be a spiral, from the circumference to the centre of the snare. Satisfied with the work, it seats itself at the centre, surrounded by the hopeless tangle of its lines.

It demonstrates conclusively the force of rhythm. All the snare needs is a few bridges, just a little stiffening of the radii so as to allow the spider to pass over. The spider knows very well how to make them. Has it not made thirty-eight of them in that particular snare ? Yet now, when they are wanted, it cannot make them. It shows that the spider works without an understanding. Also it demonstrates the rhythmic sequence. The spider is under an unswerving impulse. It cannot break away from the rhythm of the moment. Its instinct tells it that when at work on its viscid spiral it must continue till its viscid spiral is complete. This instinct the spider implicitly obeys, though, in the end, it drives it to disaster.

Is it, therefore, inaccurate to compare instinct to a chain of successive links? Each link depends on the link that precedes it, and is the cause of the link that follows. It reminds us of a man who tries to remember a forgotten line in an old poem. What does he do? He goes back over the poem. He repeats what he remembers till he gets to the lost line. Then he often finds that the act of repetition brings back to his mind what he had forgotten. The forgotten line is stirred into memory by recalling to mind the line that preceded it. Line is linked to line in the chain of memory as is impulse to impulse in the chain of instinct. But let us beware of making confusion. The two chains are altogether different. That of memory is acquired and conscious; that of instinct is inherited and blind. Nevertheless, it helps us to understand the rhythm that runs through all complicated instincts.

CHAPTER V

THE WISDOM OF INSTINCT

I take one particular instinct to illustrate the amazing foresight and wisdom that lies behind the instinctive act. This is the famous discovery of Fabre, the instinct possessed by certain wasps of inserting their stings into one particular spot in the nervous apparatus of their prey.

The instinct, as we shall see, is very marvellous. It indicates the possession of an instinctive knowledge, an apparent understanding of the internal anatomy of the victim, which is almost beyond our credibility. I select this particular instinct, partly because it is so intrinsically wonderful, partly because I can extend it by original observations, partly because certain authorities have denied it. The distinguished entomologist, Professor Wheeler, dismisses it as a mere myth.

My own observations, in the main, support Fabre's view of this remarkable act.

The Stinging Instinct

Fabre puts forward the following thesis. Certain female wasps, solitary by nature, hunt one particular kind of victim, and, having captured it, paralyse it with a sting. The wasp drags the paralysed victim to a nest, lays an egg on it, seals the nest, then disappears from the spot and never again revisits her egg. The larva attacks

the paralysed victim, devours it piecemeal, then changes into a young wasp which eats its way out of the nest.

The one part of the sequence that concerns us is the way in which the wasp paralyses her prey. In this act we see the wisdom of instinct developed to an amazing degree. For the wasp behaves as if she understood the internal nervous anatomy of her victim. She not only injects her poison into its nervous system, but actually strikes the one spot in that system which can cause the kind of paralysis she requires. Moreover these systems are arranged differently in the different species of insects captured, and the wasps have different plans of stinging to fit in with the different arrangements inside. Fabre compares them to a clairvoyant surgeon thoroughly acquainted with his patient's anatomy. Perhaps he is going too far in his enthusiasm in spite of the operation being so marvellously exact.

Here are some of his most striking conclusions :—

(1) *Cerceris tuberculata* is a powerful wasp whose business it is to chase weevils. Her stinging consists of a single stab made in the under surface of the weevil's thorax between the first and second pairs of legs. See how this fits in with the weevil's anatomy. In weevils the three nervous ganglia of the thorax approximate very closely to one another. They are packed together in a nervous mass underneath the point penetrated by the sting. Hence a single sting at this one particular point.

(2) *Sphex flavipennis* concentrates on crickets. She has a different method of stinging. Her stabs are three in number. She makes the first under the neck of the cricket, the second behind the prothorax, the third towards the front of its abdomen. This plan is best suited to the cricket's anatomy. In crickets the three ganglia

are widely separated. A single stab could not reach all three of them. Hence the Sphex makes three separate stings.

(3) *Ammophila hirsuta* hunts caterpillars. Here we find still another plan of stinging. This species makes a large number of stings, one into each segment of the caterpillar's body. Again the plan fits in with the anatomy. The caterpillar's ganglia are in a long chain. In order to bring about complete paralysis each ganglion must get a stab.

(4) *Scolia bifasciata* attacks the grubs of *Cetonia* beetles. This wasp, like *Cerceris*, makes a single sting into the demarcation between the prothorax and mesothorax. The grub is a soft-bodied creature like the caterpillar. Why, therefore, only one, and not a series of stings? Because the nervous system of the grub is concentrated in the same manner as in the victim of the *Cerceris*. Similar organization, similar method.

Now these are very remarkable observations. The wasps behave as if they knew the delicate internal anatomy of their victims. What an excellent example of the Wisdom of Instinct! We can almost agree with Fabre's exclamation that the knowledge displayed by these wasps "would make Science turn green with envy." For the instinct is perfect almost beyond credibility, an amazing combination of wisdom and ignorance. For instinct, as we know, operates blindly. The wasps strike their victims by intuitive impulse. Not only do they know nothing of anatomy: they do not even know why they make their stabs.

It must be understood that these stabs do not kill. Their purpose is to cause immediate paralysis, to render the victim senseless for weeks, and at the same time keep it alive. This condition is necessary for the growth of the larva which must have a helpless creature to attack,

and yet have food in the living state. Hence we see in every way how wonderful this instinct is.

Observations from the Tropics

For years I have been interested in this paralysing instinct. It is one which we seldom get a chance to witness. A detailed knowledge of the wasp's behaviour, an untiring patience, a continuous curiosity, an eye on the look out for every opportunity are necessary if we wish to see it at work. Eighteen times have I been present at these remarkable contests. Of each I possess a careful record. I present here four of the most striking to amplify or controvert the conclusions of Fabre.

1. *Sphex lobatus* paralysing cricket

Five times have I seen the striking spectacle of *Sphex lobatus* paralysing her victim. The wasp is large and very magnificent, coloured a brilliant metallic green that glistens with yellow and gold. She frequents the sandy wastes of India where she hunts the cricket, *Brachytrypes achatinus*, an enormous species far bigger than herself. The Sphex is met with exploring the soil. She finds a particular spot that interests her, digs into the earth, scuffles it aside, breaks through into a cricket's burrow and disappears from view. For a minute or two nothing happens. Then a large head appears at the opening and an enormous cricket comes out with a rush. In rear of it comes the infuriated Sphex. There is a fierce chase. The cricket goes off leap after leap, and after it the murderous wasp. She reaches her victim, clutches its back, fixes her mandibles on one of its wings, curls her abdomen round its flank and pushes her sting underneath its thorax. Then she gives two or three quick stabs.

They are short and sudden, and scarcely appear to penetrate the victim. I shall call them the preliminary stings. Soon she does something much more decided. She presses her abdomen beneath the cricket's thorax until its tip almost reaches the cricket's head. Then she plunges her sting straight into the cricket's neck. This stab is quite different from her preliminary stingings. It is a long, steady and determined penetration. For half a minute it remains inserted while the wasp keeps clinging to the cricket's flank. The result of the stab is instantaneous paralysis. Legs fall, antennæ droop ; the cricket

FIG. 8.—*Sphex lobatus* paralysing cricket.

lies without a trace of movement, to all appearances a lifeless thing.

Thus the one stab into the neck is the final and important one. It is difficult for the Sphex to bring it about. She must avoid the cricket's dangerous weapons, its powerful mandibles, its spinated legs. She must adjust herself correctly to the flank of her victim, gain a suitable purchase with claws and mandibles before she can make the stab into the neck.

What I have described is the usual operation. There was variation, however, in the five encounters, especially in the nature of the preliminary stings. I have said that

the Sphex first probes beneath the thorax, and makes what I called preliminary thrusts. Are these thrusts made with the intention of paralysing ? Are they genuine stabs that penetrate the integument and reach the nervous ganglia underneath ? No. The preliminary stings are merely superficial. They do not reach the nervous ganglia nor have they any paralysing effect. We must regard them as auxiliary blows, their purpose being to weaken the cricket and enable the wasp to make her final stroke. One thrust only has paralysing properties, the final one in the cricket's neck.

We must, therefore, differ from Henri Fabre in his view of the importance of the three stabs. He investigated the Yellow-Winged Sphex which made three stings into her cricket, one into its neck, a second into its prothorax, a third into the front of its abdomen. According to Fabre these three stabs are essential. The three ganglia in the cricket's thorax are widely separated. Hence the necessity of three separate thrusts.

In this view we believe him to be mistaken. We judge by the evidence of *Sphex lobatus* which paralyses her cricket with the utmost efficiency, and always by one single stab straight into the victim's neck.

We do not in the slightest differ from Fabre in his view that the sting enters the ganglia. Rather we regard it as the most remarkable of his discoveries. The behaviour of *Sphex lobatus* confirms it. For we have first the preliminary stings, which are rapid and only just penetrate the integument. These stings never cause paralysis. It is only the one final thrust that gets deep enough to reach the nervous chain. When we witness the act we feel firmly convinced that the nervous apparatus has been definitely struck. There is the prolonged thrust, then the instant relaxation of the victim, the struggling palpitating body with all its appendages

struck into the image of death. Some intense nervous dislocation must take place to cause such a shattering effect.

Another point of interest in the problem of paralysis. Fabre's crickets were paralysed permanently and lived for weeks in a comatose state. In the Indian example it is a temporary affair. Intense and complete at the time of its occurrence, the paralysis soon shows signs of passing off. For three minutes there is complete quiescence. Then we begin to see a slight movement of a leg. In another half-minute two legs work. In four minutes the body muscles contract. In another minute the palpi and antennæ quiver. In eight or ten minutes the cricket is on its legs. In thirteen minutes recovery is complete.

How utterly different from the experiences of Fabre! He records no case of recovery, though some of his crickets remained paralysed for weeks, and one for as long as a month and a half. Fabre's record is one of long-enduring coma; mine is one of rapid resurrection. It is really astonishing. A creature has been struck into the deepest paralysis and in thirteen minutes has returned to life. Nothing but a thrust into the nervous apparatus could produce such astonishingly rapid results. This phenomenon of rapid resurrection confirms the ganglionic theory of Fabre.

One cannot but speculate on the nature of the stab that can bring about this surprising result. We cannot imagine a physical disruption, a laceration of nervous tissue. Physical disruption means permanent disablement, or at least paralysis of a prolonged kind. Recovery after thirteen minutes puts such an idea out of count. In addition we have an observation from Ferton which shows that the paralysis is caused by poisoning and not by a physical destruction of nerve tissue. At Bonifacio he met with *Sphex subfuscatus* which had just finished

paralysing her grasshopper.[1] Ferton took the victim from her and replaced it by another unparalysed grasshopper. The wasp seized the second victim, operated on it in the same way as she did the first one, that is stabbed it in both neck and thorax. With what result? None, so far as the victim was concerned. The wasp's stabs caused no effect whatsoever, and the grasshopper made off in leaps. The Sphex had paralysed the first one easily. Why could she not do so a second time? Because the first operation had exhausted her poison. There was none left for the second set of stabs. It is, therefore, to the poison, and not to laceration, that the immediate paralysis is due.

How then does the poison act? Can it cause an internal inflammatory disturbance which for a time paralyses the nerves? Does an inflammation take place in the ganglia like that which we ourselves experience when stung? This idea is almost equally improbable. After so acute an inflammatory disturbance such quick recovery could never take place.

There seems to be only one explanation. The wasp injects an anæsthetic fluid, a substance which paralyses nerve tissue without causing destructive effects. Moreover it is only temporary in action. It quickly diffuses and recovery begins. The act is like the surgeon's cerebrospinal anæsthesia. The surgeon injects a fluid into the spinal tube. A paralysis of the parts controlled follows. Recovery takes place when the fluid is absorbed. This, I think, is a true analogy with the paralysis caused by the Sphex. In one way the Sphex can do better than the surgeon. He can paralyse only part of the trunk. He cannot inject at so high a level as to influence the most vital centres. The Sphex, on the contrary, is unlimited

[1] *Annales de la Société Entomologique de France*, Vol. LXXI, p. 506.

in her paralysis. The whole organization is rendered unconscious by one determined stroke.

2. *Ampulex assimilis* PARALYSING COCKROACH

Twice I have seen this particular contest. As in the case of Sphex with her cricket it supplies important evidence against some of the speculations of Fabre.

Ampulex assimilis is a small wasp which shines with metallic blue. Hundreds of them frequent the date groves of Baghdad where they hunt for cockroaches under clods and up the trunks of the palms.[1] The particular cockroach is *Shelfordella tartara*, and it is only the females that are stung. When the wasp is hunting she searches crannies until she finds one occupied by a cockroach. She disappears into the hole. A cockroach comes out with a quick rush and slips off at the greatest speed. The wasp follows close upon its heels. She may get her quarry in a moment. More often she has a long and difficult pursuit. In the end she reaches it, grips the projecting edge of its thorax, holds it firmly to the ground. Then she immediately applies her sting. In the act the wasp is almost lying on her back. Her abdomen goes in beneath the body of the cockroach : its tip is directed upward, and the sting is plunged straight into the front of the cockroach's thorax. The thrust seems to be made a little to one side, though almost in the middle line. While the sting is in the Ampulex remains motionless, gripping the thorax, rigid and still. The stinging is a prolonged operation. It lasts about half a minute, a steady and determined thrust. Its result is to stagger the cockroach, though not to paralyse it with that completeness which we saw in the cricket stabbed by the Sphex. It appears completely dazed, nevertheless its

[1] *Nature at the Desert's Edge*, pp. 35–8.

appendages move and it can stand when put on its legs.

Here again we see that one sting is sufficient to produce the paralysing effect. Sometimes, however, one is not enough. Then a second is given, as prolonged as the first, and in the same spot.

The first point of interest in this particular contest is the relation of the stabbing to the nervous anatomy. Remember Fabre's thesis. One stab where the ganglia are concentrated ; three stabs where they are far apart. Let us apply it to the cockroach. How are its ganglia arranged ? The three are separated widely. It is just the kind of victim that on Fabre's thesis would require three separate stings. Yet one stab is quite sufficient to reduce it to a comatose state. Hence we disagree with Fabre's conclusion. It is not in the "three dagger-thrusts that the infallibility and the intuitive science of instinct appear in all their splendour."

The second point is the duration of the paralysis. The Ampulex, having stabbed her cockroach, carries it off to a tunnel in a date-palm, lodges it inside and closes the hole. Immediately afterwards I uproot the cockroach. It is quite alive. It appears dazed rather than paralysed. Very soon it completely recovers. The paralysing thrust, like the Sphex with her cricket, is merely a temporary affair. This again is quite a different kind of operation from those described by Henri Fabre. What is the object of the wasp's stabbing ? Why is this transient paralysis necessary ? Merely, I think, to permit transportation, to enable the wasp to get her victim up the date-palm and bury it alive in the cell.

3. *Cryptocheilus rubellus* PARALYSING TARANTULA

The contest which Fabre longed to see was that in which the Black-bellied Tarantula was paralysed. The

assailants are so powerful, so venomously armed. The Tarantula must be a terrible victim to subdue.

Here are the details from a desert near Baghdad. I observed the act on two occasions.[1] *Cryptocheilus rubellus* is the huntress in question, tawny in colour, large as a hornet, remarkably powerful and swift. Her spider, the Black-bellied Tarantula, is immense. Ponderous, globular-bellied, with massive jaws, it lives at the bottom of a tunnel in the ground. The wasp in her searchings finds the tunnel, enters, works her way to the rear of the tarantula, drives it out of the lair. There is a brief chase. Then they face one another. The tarantula elevates itself, spreads out its legs, assumes a wrestling attitude and defies the onslaught of the wasp. Now follows a display of strategy. The wasp manœuvres to the rear of the tarantula, tries from a distance to get in a few stings, not, of course, paralysing stabs, but just a few preliminary darts into the oval belly of the tarantula. For some time this strategy continues. Now and again the tarantula gets pricked. As a result it weakens a little. Then the wasp, seizing her opportunity, makes a terrible rush. She throws herself on her victim, grips it by the back, gets her abdomen across its thorax and feels for the point to strike. The finding of the exact spot is not easy. The wasp repeatedly probes and searches, first at the front, then at the sides. At last the tip of her abdomen goes in between the bases of the second and third legs. This is the point of penetration. One long stab and the ganglia are entered. The powerful tarantula falls apparently lifeless, its paralysis is complete.

The precision of this paralysing blow convinces us that Fabre is strictly correct when he states that the sting enters the ganglia. Why is the stab always in the thorax? Why never in the head, never in the abdomen? All

[1] *Nature at the Desert's Edge*, p. 84.

that we get there are preliminary prickings, quite insignificant compared with the stab. The thoracic thrust is not easy for the wasp. She must weaken her opponent before she can make it. Then she must get herself into a difficult attitude. Also we see her searching and probing with her sting, clearly feeling for the one spot at which to make the paralysing stab. There must be something very special in this thoracic penetration. What can it be if not the ganglia underneath ? Fabre is correct in this conclusion. The wasp is not guided by what is external, but by the internal anatomy of her prey.

FIG. 9.—*Cryptocheilus rubellus* paralysing Black-bellied Tarantula.

We can learn still another lesson in instinct. Fabre did not see the tarantula paralysed, yet he tells us how it is brought about. First a sting is driven into its mouth. This is to paralyse the poison-fangs, to deprive the tarantula of its fighting weapons. Following on this comes the main stab directed behind the fourth pair of legs just in front of the tarantula's belly. How completely wrong is this conclusion ! There is no thrust into the mouth, no stab behind the fourth leg. How did he reach this erroneous deduction ? He argued from a closely allied species, a near relative of the tarantula-huntress that stabs her spider in that particular manner. Hence, argues Fabre, such is the way the tarantula is stabbed. It illustrates how different may be important instincts

in closely related animals with very similar habits. And though no one knew this better than Fabre, yet he allowed himself to be completely misled.

4. *Galeodes arabs* OVERCOMING SCORPION

This is a particularly interesting example. It demonstrates clearly the wisdom of instinct, shows the possession of remarkable prescience and instinctive knowledge of the anatomy of the prey. The encounter is quite different from those already described. The attacker is not a wasp but a Solifugid, a huge hairy spider-like creature that is met with in the desert near Baghdad.[1] Its antagonist is a large black scorpion. There is no question here of paralysing or egg-laying. What I describe is the contest that happens when the two adversaries chance to meet. The way in which the solifugid disarms its victim shows instinctive wisdom in the highest degree.

These two great creatures come together. It is a horrible and repulsive spectacle. Each is immediately conscious of danger, is vigilant, cautious, alert. They make rushes at one another, the scorpion with claws open and sting raised, the solifugid with palps thrust forward ready to receive the rush. There are many onsets, many wasted blows, many backward springs and forward rushes, but all to no effect. Soon the solifugid turns to strategy. It works round to the enemy's rear, and concentrates attention on the scorpion's sting. Again and again it seems about to advance. It is filled with terror, sometimes shakes all over, yet it keeps attention fixed on the sting. After many manœuvres and much fainthearted-ness it at last makes a ferocious spring. There is a pounce, incredibly swift. The solifugid has gripped the scorpion's tail immediately in front of the base of the

[1] *Nature at the Desert's Edge*, p. 274.

sting. Now comes a squirming, a twisting, a struggling. The scorpion battles with jaws and legs, fighting madly to get free. What does the solifugid do ? Just hangs on to the sting. It cares nothing for the scorpion's other weapons. Though jaws and legs may tear at its body, yet it clings like a bulldog to the sting. Moreover it

Fig. 10.—Solifugid crushing scorpion's sting.

makes the most of its advantage. It grinds its fangs into the scorpion's tail, crushes the organ so completely that the sting is either bitten off or its power is completely destroyed.

Here, therefore, we have instinctive wisdom. The solifugid knows its opponent's weapon, its position, its use, the deadliness of its effect. It understands that it must make a strategical manœuvre and must at all costs concentrate on the sting. Now this is a wonderful

example of prescience. How did the creature ever come by this knowledge? Where can it have learnt the lesson of the sting? It cannot be knowledge learnt by experience, for one experience of a scorpion's sting means death. We cannot imagine that the creature has been taught it. For young solifugids know the business and employ the same strategy as the adults. How, therefore, have they come by this knowledge? All we can say is that they know it instinctively. The same wisdom that makes wasps seek the nervous ganglia gives the solifugid the intuitive impulse of fixing on the scorpion's sting. It is a wisdom, intuitive, instinctive, altogether untaught and unknown.

Thus we see how wise Instinct can be. Indeed, it may be said to surpass Intelligence in the knowledge that it seems to possess. The difference, of course, is fundamental. Instinctive wisdom is inherited wisdom, a racial possession, handed down through generations, which each individual receives at birth. Intelligent wisdom is acquired wisdom. It is something which each individual learns either through experience or by being taught. Hence the superiority of instinctive wisdom. As the race is more stable and enduring than the individual, so is the wisdom of racial origin more perfect than that which the individual acquires. Its perfection is best shown by the wonderful way it operates on the first occasion that it comes into use. For these creatures have their instincts perfect from the beginning. They know full well their complicated business on the very first day they set out on their work. The wasps that get their stings into the nervous ganglia do so with the very first victim they meet with. I have reared solifugids from eggs in a box and the youngsters knew the scorpion's danger-point though they

had never seen a scorpion before in their lives. Or take the complicated spider's net with its angles, its sectors, its parallels, its spirals. We are amazed to see the spider at its first attempt manufacture with complete perfection this intricate geometrical device. All this wisdom is thus inherited. It is part of the make-up of the animal, and perfect from the very start.

CHAPTER VI

THE FOLLY OF INSTINCT

We have seen the wonderful wisdom of instinct. Let us now turn to the other side of the picture and witness its amazing folly.

Instinct, when it operates in the normal course, when it fulfils the particular purpose for which that particular instinct exists, acts with admirable wisdom and perfection. But divert that instinct from its normal course; try to turn it in some other channel; endeavour to make it do something which it was not originally intended to do, and the result is a course of action which astonishes us by its utter folly.

I could give many illustrations of this, but will mention only those which have most impressed me.

Examples from the Solitary Wasps

Observation 1

Rhynchium nitidulum is a mason-wasp that nests commonly in Indian bungalows. Its nest consists of a cluster of cells, each shaped like an oval pot. The pots are built of fine mud, which is then covered with a layer of resin.

I find a cluster of these pots. All are completed except one, which is about half built. The wasp is busy at it, coming and going, bringing with her pieces of mud.

In her absence I place on the edge of this pot a tiny pellet of mud. It is no bigger than the head of a pin, but it lies at the spot where the mason builds. The wasp returns. This strange excrescence attracts her immediately. She has been accustomed to an even edge. Here is an unaccustomed object, something quite out of her ordinary life. What will she do about it? I expect to see her grip it and throw it away. Surely that is the obvious thing to do. But what does the wasp know about the obvious? Nothing, so far as this incident shows. What does she do? She examines the nodule, then gets very agitated, then withdraws into the cell. She refuses to go on with building and is clearly very confused at this unexpected state of affairs. The nodule remains. No effort is made to throw it away.

FIG. 11.—*Rhynchium nitidulum* building a pot.

Now comes the particular act of folly. The wasp will not throw away the nodule, but she does something ridiculously foolish. She climbs on to a neighbouring cell, one already completed and covered with resin. She tears from it a fragment of this resin and smears it on the outside of her half-completed wall. Now this is very unusual behaviour. This wasp always first builds her mudwork, and when that is finished applies her resin. First mudwork, then resin; this is the invariable routine. Yet, in this case, because of my nodule, she begins to put resin on a cell that is only half built. She fetches more resin, brings piece after piece, works with the most exceptional energy, smearing as she never smeared before.

And all because she finds a little nodule on the edge of an uncompleted cell. This strange occupation is very laborious ; it keeps her busy the whole day. By nightfall the pot, though only half built, is thoroughly smeared with glue. My nodule, I need scarcely say, is still on the edge of the pot.

Now for the interpretation and the explanation of this folly. I have said that in the ordinary course of events the wasp first builds her pot, then applies her coat of resin. A tiny nodule of mud on the edge has made her feverishly smear resin on a cell that is only half built. Why does she do this ? For there is an explanation. Smearing of resin is a protective act. Without doubt it is of vital importance. Its purpose is to prevent parasites from penetrating into the completed pot. To the wasp protection implies smearing. Her natural enemy is the parasite ; her defence against the parasite is resin. Hence if her defensive instinct is roused it manifests itself in smearing the cell. Now, when she discovers my strange nodule she feels immediately on her guard. Something has been this way. There are signs of an intrusion. Her natural instinct of protection is roused. Resin must be gathered and spread quickly, else the parasite will penetrate her wall. Of course her act is utterly useless. The cell is wide open, only half built ; in it there is yet nothing to protect. But the wasp cannot reason out these simple matters. Instinct has it that protection means smearing. Hence the mason must smear.

It is an act of utter folly involving hours of profitless toil.

Observation 2

Here we see the same thing exemplified. *Rhynchium* is working at another pot. She has almost completed

the masonry. Just a few more bits of mud will bring the wall to its full height. I place a fragment of camphor in the cell while the wasp is absent getting mud. Soon she returns. The smell distracts her, for she loathes camphor. She tries to face it, struggles to build, but cannot do so in the horrible stench. What does she do ? Perhaps try to pull out the camphor. Not at all. She could not pull my pellet from the wall. How can she have the wit to pull out the camphor ? She does exactly what she did in the previous experiment. She falls back on the futile resining behaviour. Resin is torn from neighbouring cells and is smeared with feverish energy all over the uncompleted wall.

Again we see the folly of instinct. The cell has been invaded. Therefore smear. Smearing, of course, is an excellent performance at its proper time and place. When a cell is finished, then smearing is essential. The gluey substance makes a splendid barrier. Parasites stick to it and cannot get through. But see its hopelessness on other occasions. How could smearing keep parasites out from a cell that is partly built ; or how could it be of use to the wasp so long as the camphor remained inside. It illustrates well the commencement of our chapter. Instinct is wise in its normal course. But try to make instinct do something else and the result is an astonishing folly.

Observation 3

This has been made on a digger-wasp. It completely confirms a somewhat similar experiment made on a *Sphex* by Henri Fabre.

Psammophila tydei, a digger-wasp, frequents grassy patches in the Himalaya.[1] Her business in life is to find

[1] *A Naturalist in Himalaya*, p. 193.

a caterpillar, paralyse it, lodge it in a burrow, lay an egg on it, seal the mouth of the burrow, then disappear and come no more to the nest.

I find a wasp that has paralysed her victim. She has lodged it in the nest, laid her egg on it, and is engaged at closing the hole. This is done with small pebbles and flat pieces of slate. Dust and sand are then brushed on top. Finally the whole is consolidated by the insect ramming it with her head.

Now comes our chance to see the folly of instinct. When one-half of the tunnel is filled in I break into it, and extract the caterpillar from the cell at the bottom. Attached to one side of the caterpillar is the wasp's delicate egg. I place the caterpillar, with the egg attached, right across the entrance to the tunnel. The question is: What will the wasp do when she comes to resume her filling? Why, of course, anyone would say: "She will stuff back her egg and caterpillar, then fill in the hole." Let us see. The wasp returns. She finds something quite unexpected; her egg and caterpillar at the entrance, nothing at all inside. There is no good her resuming the filling unless she first gets these things back. Yet that is exactly what she does do. She goes to the entrance, begins to fill it. She treads on the caterpillar, but refuses to notice it. She drops in pebbles, shuffles in earth, works just as if nothing had happened; yet under her feet is the pillaged victim and before her the empty cell. She just continues where she left off; in fact, resumes her labour just as if nothing had happened and everything was in perfect order. In the end she fills it to the brim, scatters dust and pebbles over it so as to hide all trace of it from view.

Instinct impels her to this utter folly. Her instinct is to fill the tunnel, not because she knows that the tunnel wants filling, but just because filling is the impulse

of the moment. Therefore she must fill. It is nothing to her that the work has been disordered. She must just fill.

Observation 4

Here is another observation from the East.[1] The Rev. C. P. Cory, Archdeacon of Rangoon, watched a mason-wasp, *Sceliphron intrudens*, building her nest on the mantelpiece of his study. Having finished her nest, the wasp began to decorate it. She coloured it and shaded it with the utmost care, making it exactly like the bark of a tree. For a fortnight she worked at the ornamentation. She made little grooves on it like those on the bark ; she mottled it with a mixture of green and yellow clay ; she brought green chalk and white chalk to make patches of lichen on it : she fetched bits of grass to act as tiny twigs. In the end the resemblance to bark was marvellous, and the whole was quite an artistic piece of work.

See the folly of instinct in this particular case. Those fourteen days of artistic labour would be highly valuable under normal conditions, namely when the nest is fixed to bark. The instinct is, no doubt, of vital importance. By blending with the bark the nest is concealed. But the wasp in this instance builds on a mantelpiece. There the decoration is quite useless. It is even worse than useless, for it increases the conspicuousness of the nest. But the artist does not know this. Instinct just impels her to paint ; and paint she must, foolish or not. How full of surprises is this psychic force, so wise when following its normal channel, so foolish when faced with unaccustomed events !

[1] *Journ. Bombay Nat. Hist. Soc.*, Vol. XXII, p. 648.

Observation 5

An allied species, *Sceliphron madraspatanum*, has been seen making blunders equally serious. Mr. Dutt, an Indian observer of Hymenoptera, puts on record the following facts.[1]

Sceliphron makes a nest of cells. She builds these cells with pellets of mud piled one on top of the other. When the cells are finished she brings more pellets and covers the whole cluster with mud. Now Mr. Dutt saw one of these wasps making her nest on a glass window. The nest consisted of two cells. The wasp had finished building her cells and was beginning to bring pellets with the intention of covering them with mud. At this stage in the operations Mr. Dutt interfered. When the wasp was absent looking for a pellet, he scraped off the two cells. The wasp returned with her load of mud. Her nest was gone. She could throw away her pellet. It was of no further use. But the wasp did not think so. She began to spread her pellet over the traces of her scraped-away cells. On to the glass went her smearings of mud. It was not just a casual error, or a mere way of getting rid of a burden. For she worked with all her usual earnestness. Also when she had finished that pellet, off she went and fetched another, and kept on bringing pellet after pellet until the area previously occupied by these cells was completely covered with mud. It is really almost unbelievable that the unswerving force of instinct can lead these creatures so hopelessly astray!

Examples from Caterpillars

One cannot discuss the folly of instinct and omit that remarkable experiment made by Fabre on the Pine Processionaries.

[1] *Memoirs of the Department of Agriculture in India*, Vol. IV, p. 215.

These caterpillars live in pine trees, and march about in long processions. All in the procession follow one another, head to tail, in single file. Hence the name "Processionary." They march in a continuous string.

The string of caterpillars crawls along a thread. Number one in the string pays out a line. Wherever he goes he dribbles it behind him. Number two steps on his thread, adds to it a thread of his own, and thus doubles the line. Then comes along number three, who contributes his thread and trebles the line. And so it goes on through the whole procession, which may amount to hundreds of caterpillars. Their combined efforts make a road, a glistening ribbon of silk.

What is the purpose of this silken road? In the first place it is a social bond. It links all the caterpillars together. Then it serves as a guiding track. The procession, by following it backward, can at any time return to the nest. Their safety depends on the road they manufacture. They are firmly bound to it and cannot leave it. Each caterpillar follows the path of his predecessor; all are linked together by threads.

Fabre thought of making the following experiment. What would happen if he got his caterpillars to follow one another in a closed circuit? All would then be exactly equal. None would be leader, none follower. A complete procession on a circular track would be without beginning or end.[1]

The idea was difficult to carry out. At last, however, he got his procession marching round the edge of a large vase. The circumference of the vase was a yard and a half. The procession formed a string around it, a completely closed circle of caterpillars, no leader, all followers, an endless file along an endless track. He had brought about a state of affairs that could never occur in ordinary life.

[1] *The Wonders of Instinct*, pp. 133–47.

What happened ? How did the procession behave on this interminable path ? Did they go on for an hour or two, then realize that they gained nothing and break away on another road ? The experiment began on the 30th January. At midday Fabre got them on the circle. All that day they went round and round. Evening came, and they were still at it. Fabre was stupefied, amazed. Next morning he saw the gyration continuing, and so on throughout that day. The third day came. Still it went on. There was frost in the air, and the cold numbed the caterpillars. They had no food, and starvation weakened them. At night the call of the nest allured them, yet they could not break from the everlasting circle and strike a new course of their own. Day after day they stuck to their circling, tied to that fatal thread. This went on for seven days and nights. On the 6th February deliverance came. More apparently by accident than by design, some of them managed to break from the circle and escape the interminable routine. The spell ended on the eighth day. Eighty-four hours had been spent in walking. They had travelled more than a quarter of a mile.

Of all experiments this must be the best to demonstrate the abysmal stupidity of instinct when working out of its accustomed course.

Examples from Ants

I will give two instances from my own observations.

Observation 1

Messor barbarus is an Indian ant which collects the seeds of native grasses and carries them into its nest. When they get them inside they peel them and store them and carry out the discarded husks to a special refuse heap of chaff. The nest is situated in the ground. The refuse

heap is made about 8 inches away from it. Every husk goes on the heap. An excellent arrangement! The object, of course, is to keep the husks quite clear of the entrance to the nest.

Everything goes well under normal conditions, that is when the nest is situated on the ground. But one day I found a nest on a vertical wall, a situation quite out of the ordinary.[1] Numbers of ants were entering and leaving it; some were carrying in seeds, others bringing out discarded husks. Now, a nest in such an unusual situation might at least have one advantage to the ants. When they carried out their discarded husks all they need to do is just drop them at the entrance. There is no necessity to carry the husks 8 inches away from the nest. Even if they did so they could not make a heap. Let them just drop their burdens from the entrance and they will be saved the considerable labour of transporting thousands of husks. But the ants, to my surprise, could not see this. Each individual bringing out a husk transported its burden 8 inches down the wall, then laid it carefully against the wall just as if it were making a heap. A heap on a vertical wall was impossible, and the husk, of course, fell to the ground. Yet for months the ants continued doing this. They never learnt to give up the useless journeys and to drop their husks from the nest mouth.

Again we have the same explanation. The instinct to make a husk-heap is very valuable. It works perfectly under ordinary conditions, that is when the nest is on level ground. But make a change in those ordinary conditions. Place the nest on a vertical wall. A husk-heap then becomes an impossibility. The attempt to make one is just useless labour. Yet the insects cannot appreciate the situation. Their natural instinct is to

[1] *A Naturalist in Himalaya*, p. 41.

have a husk-heap, hence they go through the routine of making it even though a husk-heap cannot be made.

Observation 2

Another observation shows the same stupidity. *Myrmecocystus setipes* is a large ant met with on the North-West Frontier of India.[1] It has an interesting way of excavating its nest. Some of the ants carry out earth ; others are detailed to remain outside, their business being to sweep away the dust and so prevent it falling back into the nest. As in the case of the previous observation, I happened to find one of these nests on the face of a vertical bank. It was situated on a perpendicular surface 3 feet above the level ground. The ants were busy excavating earth. Each ant carried out its load, marched with it 6 inches down the bank, then placed it against the bank from where it, of course, dropped to the ground. This act in itself was folly, the same folly as was shown in the case of the husks, for the ants would have saved themselves much labour had they dropped their loads at the mouth of the nest.

But what was my surprise when I looked to the ground 3 feet below the nest. There I saw more stupendous folly. Down below were six busy ants. They were working feverishly sweeping back dust, just exactly in the same way as they do around the mouth of a nest. Yet in this case the nest was 3 feet above them. The ants were, therefore, sweeping dust from an opening into which it could not possibly fall. The reason, of course, is that instinct impels them. To the ants excavation involves sweeping, an excellent task under normal conditions, but utterly foolish in that exceptional circumstance when the nest is situated on a vertical bank.

[1] *A Naturalist in Himalaya*, p. 58.

Observation 3

The reader will remember the Pine Processionaries, how Fabre made them march in an endless circle round and round the rim of a vase. Caterpillars are naturally stupid creatures. We cannot expect much of their mentality. But who would anticipate an equal stupidity amongst such adaptable creatures as ants. Nevertheless such is the case.

Professor Wheeler records an observation which very much reminds us of Fabre's Processionaries.[1] He kept a colony of *Eciton schmitti* confined in an artificial nest. The nest consisted of a glass jar standing on a board surrounded by a water moat. These ants belong to the hunting tribe. Their method is to send out columns which capture everything suitable they meet with.

Let us see what they did in the jar. After wandering about inside it, the colony made its way over the edge, then down the outside of the jar until it reached the base. Then it took a turn to the left and made a complete circle around the base of the jar. The circle thus formed became a closed one. It must have been like the closed circle that Fabre's caterpillars made on the vase. What happened then? They kept on circling. Round and round the base of the jar they followed one another like so many sheep. The mode of progression was perfectly normal; it was exactly the same as what takes place on their hunting expeditions. The circling was the thing that was so ridiculous. For the ants kept religiously following one another, apparently without the faintest idea that they were always on the same path. This went on for forty-six hours. It must have been a ludicrous spectacle. Fabre, we saw, was stupefied at his caterpillars. To Wheeler this was an "astonishing exhibition."

[1] *Ants*, by Wheeler, p. 265.

Think of its uselessness and blind stupidity. For two whole days these ants kept circling, each one repeatedly touching its predecessor, all of them scenting the smooth track, pushing on, hastening, trying to get forward, yet never making the slightest progress, but circling perpetually on the same path.

How machine-like is this instinctive impulse! One wheel grips in another wheel; the other wheel fastens in a third wheel, and thoughtlessly, undeviatingly, unknowingly, it works towards some predestined end.

Examples from Spiders

I am tempted to give some illustrations from spiders.

The common house spider, *Agelena labyrinthica*, weaves a silken bag around its eggs. The manufacture of this bag is tedious and difficult. Its purpose is of necessitous importance, namely to protect the delicate eggs. It is a very simple experiment to remove the eggs as the spider lays them. They are gone. Therefore the bag is no longer needed. Nothing is left to be wrapped up. So it would seem. But the spider does not think so. She goes on making the bag according to her original intention. The work is carried out in the orthodox manner, just as tediously, just as laboriously as if the full cluster of eggs were present. All the labour goes for nothing. In the end there is a perfect bag which wraps up nothing at all.

Every one knows of the trap-door spiders. They make long narrow tunnels in the soil with a circular entrance flush with the surface. They provide the entrance with a lid fashioned in the form of a hinged door which accurately closes the circular hole. Now these spiders

are so careful about protecting their tunnels that they cover the doors with such material as will make them blend with the surrounding ground. Many of them live in mossy surroundings. Moss, of course, is what they require. So they collect it and grow it on their doors. The result is to make the door invisible. It blends with the surrounding moss. Let us interfere with this valuable behaviour. We will alter conditions and make the instinct bring about exactly the opposite effect. Cut away the hinged door and at the same time remove the surrounding moss. A circular entrance without a door now opens on a patch of bare ground. What does the spider do? Just exactly what it is her impulse to do. First she makes a new door. But that is not sufficient. She carefully covers it over with moss. The result is a structure glaringly conspicuous, a vivid green circle of moss in the midst of a brown patch of earth!

What folly, we exclaim, in all these actions! Why can't the creatures just think a little and not fall into these stupid traps? They can't do so, for the instinct that impels their actions demands fulfilment, whatever the cost. Are they then nothing but blind machines? Certainly the evidence advanced in this chapter credits them with scarcely a glimmering of sense.

But such a conclusion is quite unwarranted. We are dealing with instinct in its crude manifestation. As yet we have not touched on that course of behaviour which supplies evidence of a higher type of mind. The conclusion that we draw is not that insects are machines, but that their instincts, so amazingly exact and deliberate, have been given them only for one definite end. When applied to that end they are astonishingly perfect. They act with foresight, with unerring logic, with results which

seem even to surpass our reason. The wasp must keep parasites out of her cell. What does she do ? Smear the cell outside with glue. The caterpillars have to keep in a procession. What do they do ? Cling to a thread. The trap-door spider wants to hide its door. What does it do ? Cover it with moss. How foreseeing, how logical, how wise it is ! Our reason could do no better. Perhaps it could not do as well. But divert the same instinct. Alter its course. Try to make it do something else. Give the wasp an enemy other than a parasite ; make the caterpillar's thread into an endless circle ; take away the mossy environment of the spider. We have seen the result. Instinct goes on oblivious of such changes. Darkness takes the place of light.

CHAPTER VII

THE LIMITATIONS OF INSTINCT

As the preceding chapter will have led us to suspect, instincts are confined within fairly strict limits. I do not say that they are absolutely fixed. We shall see later that they can vary beyond the normal limits of the act. But considered broadly, an instinct is limited. Within its limits it produces wonders. Beyond those limits it cannot go.

I will give some examples from different groups to illustrated this point of view.

Examples from Wasps and Bees

Those wasps that drag paralysed victims to their nests usually do so on a fixed plan. One species grips her prey by the palpi, a second hauls it by the antennæ, a third gets hold of the victim's leg. Each sticks to her own method. A *Psammochares*, for example, that hauls on a leg will stubbornly refuse to grip a palpus : an *Ampulex* that uses the antennæ will not haul on a leg or wing.

It is easy to test this. *Ampulex assimilis* chases cockroaches at Baghdad. The wasp always hauls by the antennæ. I see her getting the victim up a tree. She has a grip of its antennary threads, and is marching it up the trunk. I cut off its two antennæ. The wasp seizes the broken stumps. Her tow-ropes, of course, are much shortened, yet they do her fairly well. I then cut

them almost flush with the head. Just the merest tags of antennæ remain. Yet the wasp manages to get a hold of them. There are many projections she might grip more conveniently. These tags are about the most difficult of all. But the wasp stubbornly goes for the tags. To go anywhere else would mean doing something outside the normal limits of the instinct. This the wasp refuses to do. Hence the tags, or nothing at all.

Bramble-Bees in their nesting-operations can be made to show the limitations of their instincts. These bees can be got to nest in tubes, and it is a simple matter to interchange the tubes. This has been done by Dr. Balfour-Browne.[1] A bramble-bee had stocked a tube and was about to close it with a door. When the bee was absent the tube was removed, and an empty tube put in its place. What did the bee do on her return? She built a door on the empty tube, though it was clear from her behaviour that she knew this tube was not the correct one. Again, a bee was about to close her door. She was given a tube which already had a door. What did this one do? She went on adding material to the already completed door. In both cases we see limitation. The bees had to continue the course which lay within the normal limits of their acts.

Fabre gives another delightful illustration.[2] The bee was *Chalicodoma sicula*, a species that builds a mud nest. This bee is scrupulously clean about her building. If she finds any strange object in her cell she immediately pitches it out. There must be no trace of foreign material

[1] *Concerning the Habits of Insects*, pp. 47, 48.
[2] *The Mason-Bees*, pp. 188, 189.

which might injure her egg or grub. Now Fabre played a trick with respect to this instinct. He began by sticking a straw in the cell when the bee was engaged in provisioning it. The straw stood up in the cell like a mast. Nevertheless the bee, by dint of great efforts, got hold of the mast and dragged it out. Except for the heavy pull required, there was no special difficulty in the act. He then waited for the bee's last visit when she would come to close the cell. Things would then be a little more complicated. At her last visit the bee does two things: she lays an egg and she closes the gate. She has in her jaws a pellet of mortar with which to fulfil the second of these acts. Now, see what happened. The bee arrived, laid her egg, and at that moment, immediately after egg-laying, Fabre planted the straw in her cell. As in the first experiment, it stuck up like a miniature mast. What did the bee do? In her jaws was the pellet of mud. Thus her instrument was not free for action. Well, she need only just drop the pellet, then she can pull out the mast. Nothing ought to be more easy. In the first experiment she pulled it out immediately. Now what did she do?

She just left it where it was. She could have pulled it out, but she didn't do so. On the contrary she closed the cell, went off, fetched more mud, and in the end sealed the straw in the thickness of the plug of mortar. Fabre did the same with eight cells, and all ended with a straw mast sticking up through their mortared lids. How limited is the creature's instinct not to prepare against such a calamity! For a straw in the cell is a calamity. It will interfere with the young bee's growth. Yet the creature cannot avoid the calamity. Her jaws happen at the time to be engaged. They are gripping the pellet intended for mortaring, and are, therefore, not free for any other kind of work. To pull out the straw would

require some deviation. The bee would have to turn from mortaring and lay aside her pellet for a moment. But this, though so little, she finds impossible. Her limited instinct prevents it taking place.

There is a bramble-bee, *Osmia cyanoxantha*, which makes a peculiarly odd mistake.[1] This bee nests in holes in rocks. Having stocked the nest, she plugs the hole, of course with the intention of keeping out parasites. Sometimes a nest may have two openings; then the bee closes both. Here we have what looks like forethought. But we must beware of giving credit to the bee. For sometimes on the rock there are a number of holes, some of which may connect with the nest, while others end blindly and have nothing at all to do with the nest. In such a situation what does the bee do? Why, the foolish creature plugs all the holes, both those which lead to her nest and those which have no connection at all with it. She stuffs them with her usual meticulous care, though what can be the good of her plugging up tunnels which are separated from her cell by a barricade of rock! Her instinct seems to consist of an impulse to close every hole in the vicinity, and she acts as if unable to discriminate whether the hole needs plugging or not.

Such behaviour seems extraordinarily limited. Yet it is this very limitation which makes instinct so remarkably exact. In the same category come those foolish wasps which struggle against some unsurmountable obstacle to nest in some impossible hole. Witness the act of *Sceliphron violaceum*, trying to push spiders up

[1] *Annales de la Société Entomologique de France*, Vol. LXXXIII, p. 90.

into a nest. This is an Oriental species. She comes into bungalows and nests in holes. Sometimes she finds a hole in the roof, one that opens downwards into the room. This hole she tries to stuff with spiders, of course pushing them up from below. The job is very difficult, almost impossible. In the first place the wasp cannot get a foothold. Second, her spider drops out immediately after she pushes it in. Yet the wasp persists for weeks at these efforts. Undaunted she goes on stuffing and stuffing. She never seems to realize that she achieves nothing. She behaves as if she had no idea that she had chosen an impossible hole. Perhaps she has some reason for this strange selection. But it strikes us as an odd limitation of mentality. A little search would find numbers of other holes far better suited to the job.

Social wasps, though so highly organized, sometimes perform acts of very limited mentality. Kill some and place them near the nest, the wasps will cut up their comrades' bodies and use the pieces to feed their young. The Peckhams obstructed the entrance to a nest by placing some blades of grass across it. The grass caused the wasps much inconvenience, yet it never occurred to them to drag the stuff away. It is not unusual for the young of these wasps to tumble out of their cells. It happens because the larvæ, as they grow, have to change their positions inside the cells. The odd thing is that the wasps cannot replace them. They pitch their larvæ out of the nest just as if they were bits of earth.

Insects, which have to do a thing once in their lives, are often unable to do it twice. Not because they have not the weapons to do it, but because the impulse, having

operated once, is incapable of operating a second time. Certain Gall-Insects illustrate this. If a loose bag of gauze is tied around a gall, the gall-insect is easily secured. The insect makes its way out of the gall, but seems unable to perform the easier feat of getting through the gauze. Its perforating instinct is limited to one effort. Hence it cannot repeat the act.

Instinct must seem to us like an instrument made to perform a particular job. It does that job with extreme perfection, but by virtue of the very fact that it is so specialized, therefore its work as an instrument fails outside the limits of its particular job.

Examples from Beetles

I met with some good illustrations in India. *Onthophagus capella* delights in dung. The beetles' habits are briefly as follows. They find a pad of dung, get underneath it, and make vertical burrows in the soil. The bottom of the burrow becomes their home. When they want food they ascend into the dung, gather a quantity of the material and bring it down into their dens.

Here is the first experiment. When the beetles are in the dung collecting material I place a layer of paper under the pad. The whole of the paper is not covered by the dung. There is all round a projecting margin of three-quarters of an inch. I wait to see what the beetles will do. The time comes for them to leave the pad. They have collected armfuls of material and must now get it down into their burrows. The paper stops them. They cannot descend. What do they do? Of course, one would say, crawl round the edge of the paper. It is only a journey of three-quarters of an inch. Then they can immediately get into the ground. There are a dozen of them in the lump. All are anxious to get to their dens.

But they cannot do it. They scrape at the paper, try to get through it. They rake at it and kick at it for a whole day. Not a single one of them walks round the edge. I find them still at it after twenty-four hours. I then leave them for three days. Even after that time some of them are doing it, trying the same game of digging through the paper, and never thinking of walking round. Others have deserted the piece of dung. Not one has walked three-quarters of an inch and penetrated into the soil. In this we see the strictest limitation of instinct. The beetle's instinct is to travel vertically, to ascend for its dung, to descend into its burrow. A deviation to one side is not part of its instinct, and the insect cannot think of such a thing.

The same is shown in another way. I put two beetles in a glass tube, then half fill the tube with sand and place it vertically on a table. What do the beetles do ? Why, they just dig up through the sand and escape at the mouth of the tube. I repeat the experiment and modify it slightly. Instead of placing the tube vertically, I lay it horizontally on the table. What do they do now ? Of course, as before, try to escape. But how do they try it ? They first try to dig up, then try to dig down. The glass stops them in both directions. Yet they will not dig in any other way. Occasionally they go just a little to one side, but soon they return to the up and down. If I turn the tube in the vertical direction, then the beetles will easily escape. But I keep it horizontal, and the beetles keep to their up and down efforts. I leave them there all day. When I return they are still at it. I leave them for the night. In the morning one is dead. The other is trying in a languid way to burrow up and down. Though highly efficient in the art of digging,

yet the beetles refused to dig to one side and escape from the open tube. Again we see that strict limitation to the established routine of life.

It reminds us of one of Fabre's observations. His beetles were corpse-buriers, *Necrophorus vestigator*. He kept some confined beneath a wire cover. There was earth on the floor into which they could dig. The beetles habitually tunnelled into it. Up and down they climbed in their vertical wells, interred corpses placed on the earth, for months explored the inside of their cage. Hundreds of times they excavated tunnels. Yet scarcely one of them succeeded in escaping. Why? Because their tunnellings were confined to the vertical. They could not extend them a little to one side. If they made just a small elbow in their passage, it would bring them under the edge of the cover, and they could easily get out. But elbowing was not part of their digging-instinct. Hence they were unable to escape.

Examples from Caterpillars

Many caterpillars live in societies. It is merely a family union. All have come from the same batch of eggs. On such occasions they often make a nest, a common structure which shelters the lot. Now, though they are able to build a nest, yet they seldom can make much attempt to repair it. Take, for instance, Processionary caterpillars. They make a nest in the leaves of a pine tree, partly of pine leaves, partly of silk. Cut a piece out of one of these nests. We might think that the inmates would gather round and close it. But, in reality, they seem indifferent to what has happened. Gradually a kind of repair is effected, not by any mental effort of the

caterpillars, but because their habit is to lay a thread when they move about from place to place. Consequently as they wander over the breach they continually spread threads across it, and in the end it gets closed with a web.

In India I met with a better example. The caterpillar is *Margaronia caprinodes*. It is very large, yellow in colour, decorated with stripes and spots. A dense congregation of these caterpillars makes a nest in a large leaf. Their method is first to fold the leaf, then unite its edges with silk. In this way they get a common habitation, part of the wall consisting of leaf, part consisting of silk. Now these caterpillars eat the leafy wall of their house; in fact, the leaf is both home and food. But as fast as they eat holes in the leaf, they close the holes thus made with silk. As the leaf diminishes, the silk increases. Thus the nature of the habitation slowly changes. In the end they have a house exclusively of silk.

Now to show the limitation of their instinct. I took some of these caterpillars from their house and put them on an open leaf. Soon they began to feed. They attacked the open leaf as if it were their house and made holes in it in the usual way. But the point about their behaviour was that as fast as they ate holes in the open leaf, equally fast did they close them with silk. Of course the closing was just wasted labour, also a waste of valuable silk. Nevertheless the routine of instinct demanded it. A hole in a leaf means a closing with silk. A valuable sequence within the nest, but quite useless on the open leaf.

Examples from Spiders

The instinct of spiders seems particularly limited. They are very little able to escape from routine.

For example, it is quite a usual thing for spiders not to know their own egg-bags. The Lycosids are a group of wandering spiders which keep their bags of eggs attached to their abdomens and drag them about wherever they go. Nothing is easier than to rob the egg-bag and replace it with something else. Take away the bag. Give the spider in exchange a nodule of pith, a pellet of cork, a ball of paper. The spider will accept any of these and fasten on to it in the usual way. Then it will go off perfectly satisfied, and quite oblivious to the trick that has been played.

The Peckhams made a more obvious exchange.[1] Their spider was *Pardosa pallida*. They robbed the egg-bag, peeled the skin off it, then spread the skin round a lead shot about the same size as the egg-bag. The weight, however, was very different, the shot being three or four times heavier than the eggs. They gave it to the spider. She accepted it. The load was so heavy that she walked with difficulty. Once it fell off, and she spent thirty minutes trying to fasten it on again. How strangely limited is this instinct of maternity not to be able to distinguish its eggs from four times their weight of lead!

There are certain spiders in India which place their egg-bags in chambers made by twisting blades of grass. One species, *Sparassus lutescens* twists it into an elegant spiral. I took the opportunity of testing her instincts. For instance, I break the silk tissue of her egg-bag and scatter the eggs inside her chamber. What does the owner do? One would say, collect the eggs, spin a little silk and put things right. But no. The spider does just nothing at all. She lives on with her eggs all

[1] *Journal of Morphology*, Vol. I, p. 418.

scattered around her. Her mind is quite incapable of thinking out the problem of repair.

Here is another test. One of these spiders has a clutch of eggs. I add to the clutch forty more eggs taken from the brood of another individual. The spider accepts them. She has a double collection. But that is nothing to her. One could not expect her to be able to count, but she does not possess the simple wit to know if the number is more or less.

I try the same with the young spiders instead of the eggs. I rob one individual of her youngsters until she has only four left. I double the size of another's family by giving her those that I have robbed from the first. What do they do? Again, nothing at all. The one with the four is quite satisfied with her few: the one with two families is equally content. What does it matter? The maternal instinct is so limited that it cannot differentiate between more and less.

And as it is with numbers, so it is with property. I take an egg-bag from one and give it to another. The bag is accepted. The creature does not know its own property. Possibly, like the Peckhams' spider, it might have been satisfied with a piece of lead.

I made more of these exchange experiments. For instance, I interchanged the spiders in their chambers; also I robbed one of its eggs and replaced them with a crowd of young. Always the same result. The spider does not know that anything has happened and takes anything it gets.

But here is a better illustration. I pull the egg-bag from a spiral chamber and lay it just outside the entrance. This is a terrible tragedy for the spider. Her house has been built to protect this egg-bag. The sun is intense at

this season of the year and the eggs must be kept under a roof. Something, therefore, must be done, just something very simple. The spider must just catch hold of her egg-bag and pull it back into the house. It is the simplest act of a moment, and one quite within the spider's powers. But what does she do? First examines the egg-bag and crawls all over it. Then I expect to see her pull it in. But what does the foolish creature do? She shoots out threads and begins to anchor it. She fixes it all round with a delicate skein just as if it were inside her house. The sun pours down on it. Its occupants are burnt up. Nevertheless it remains outside. The senseless creature cannot pull it half an inch back into the shelter of her house. Just, of course, because pulling is not part of her instinct. Other spiders always pull their egg-bags after them; the instinct of this kind is to fix it at one spot. Fixing, anchoring, these are her duties. When anything happens to go wrong with her egg-bag all she can think of is anchor and fix. Pulling would require a slight gleam of originality, and her instinct is too limited for this.

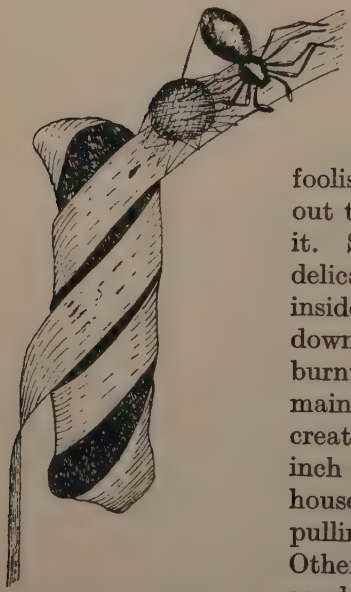

FIG. 12. — *Sparassus* unable to replace egg-bag, and, in consequence, anchoring it outside chamber.

It illustrates the gulf between instinct and reason. A creature can fashion that elegant spiral, yet it has not the wit to pull its egg-bag inside!

What can we think of the instinct of a spider which allows her young ones to be slowly devoured underneath her very eyes. Yet this happens in the genus *Lycosa*. There is a parasite, *Mantispa styrica*, whose larva penetrates the egg-bags of these spiders, gets in amongst the eggs, and eats up the young spiders. Having committed this carnage, it remains inside and develops in the egg-bag. Now, the mother shows no hostility to this monster. She allows it to enter, allows it to destroy, and continues to protect her egg-bag during the whole period of the development of the *Mantispa*.[1]

I have said that certain insects can do a thing once but are unable to repeat the act. The gall-insect was an example of this. We find the same incapacity in spiders. Lycosid spiders, which live in burrows, make their excavations when quite young and occupy them all their lives. Now, extract one of these Lycosid spiders and place it in a cage on a layer of earth. What will it do? One would say, make a new burrow. It possesses the implements and strength to do it. It has already done so before, therefore it knows the burrowing trade. Its one desire is to get underground. Once there all will be well. But somehow it seems unable to dig. Make a tunnel, and the spider will immediately occupy it. But the creature cannot think of digging for itself. Digging was once its speciality, perhaps the most important duty of its youth. Grown up, it has completely forgotten the art. It cannot reoriginate the digging instinct, so it wanders about till it dies.

These incidents illustrate very clearly the tremendous gulf between instinct and intelligence. Any one of them would illustrate our point, but take the spiral-twisting

[1] *Cambridge Natural History*, Insects, Part I, pp. 464, 465.

instinct of the spider. It bends a blade of grass into a spiral-shaped chamber, quite an elegant kind of structure and made with consummate skill. But that is the end of the spider's capacity. The making of the spiral, being instinctive, represents all that the creature can do. It is the sum and total of its knowledge. Outside the limited confines of the instinct the creature is utterly lost.

How completely different from intelligent activities. A creature that could do such an act intelligently would be free to branch off in all directions and would show originality in every field. If it could make a spiral intelligently then it could make a thousand other things of many and diverse kinds.

CHAPTER VIII

THE VARIABILITY OF INSTINCT

Instinct, we have seen, is remarkably machine-like. It looks as if it worked on an unalterable plan. But the picture has another aspect and one which must be examined with care.

Do instincts vary ? The question is one of first importance. For our view of their origin will depend on the answer. If instincts do not vary, they are permanent, unchangeable. What they are, so they have been always, and so, presumably, they always will be. If, on the other hand, instincts vary, then we have the necessary material for change. They will have been subject to the laws of evolution. Each instinct will have had its individual history. It will have come from something that was different in the past, and will be on its way to a different future.

How does Fabre answer the question : " Are the habits of an insect capable of modification ? " His reply is a decided negative. " No, decidedly not, if the habit in question belongs to the domain of instinct." Now Fabre was a determined anti-evolutionist. Anything that savoured of Darwinian philosophy called forth his most caustic satire. He saw nothing in it. To him it was " no more than an ingenious game in which the arm-chair naturalist, the man who shapes the world according to his whim, is able to take delight." Hence Fabre was dead against instincts varying. What instinct is

to-day, so it has been always. "The gift is original, perfect from the outset; the past has added nothing to it, the future will add nothing to it. As it was, so it is and will be."

We have to combat this rigid view. Variation occurs all through Nature. We might almost regard it as the essence of existence. And not variation in structure only, but variation in every instinct. We may look on instincts as we look on individuals or organs. No two individuals are exactly alike; no two organs are precisely similar, so do I believe that there is endless variation in the performance of every instinct.

If that is so, then everything is at hand for Natural Selection to work on and make use of. If instincts vary, selection will follow. Advantageous variations will favour the individual; harmful variations will accentuate its struggle. The favoured will survive at the expense of the unfavoured. To this heredity will add its influence. Advantageous variations will be preserved; the harmful ones will be steadily eliminated. Gradual progress will take place according to the well-known principles of Darwin.

But all will depend on variation. Hence we must show that instincts vary.

Examples from Solitary Wasps

Take the instincts of hunting-wasps, which sting their victims with surgical precision and then drag them off to a nest. Although the instinct of each species is fixed, yet the more we observe them the more we detect small variations of every kind. In fact, we can see in different individuals decided traits of individual behaviour.

Take *Sphex lobatus* in her manner of hunting. One individual will be hurried and impatient: another will

be more slow and precise. Her stinging operation, though fixed in plan, varies with respect to detail. Her method is to make preliminary stings, blows for the purpose of weakening the victim, before making the final stab. These preliminary stings are very variable. I have sometimes seen one sting, at other times two or three, once as many as five. Then this *Sphex* has the habit of malaxating her prey, that is of biting into its neck, probably as an accessory to the sting. But this malaxation seems quite optional. The wasp may do it once, or neglect it altogether, or repeat it a number of times. *Ampulex assimilis*, when stinging her cockroach, also shows decided variation. Her plan is to give one stab, but at times I have seen her give two. She is not bound to the strictest routine. Fabre, though so insistent on instinctive rigidity, himself quotes some similar examples. He notes a *Sphex* making two stings, when her normal instinct is to make three. Also he saw a remarkable instance where an *Ammophila* stung her caterpillar from tail to head instead of as usual from head to tail. Ferton again and again insists on the rigid character of these wasps' instincts. Yet he met with some striking examples of variability. In Corsica he found that *Pompilus effodiens* paralysed her spider with two stabs : while the same wasp in Algeria made no stab at all, but fixed her egg to the unparalysed spider. He even saw one of these wasps vary in the direction of becoming a parasite. This was the species *Pompilus rufipes*. Her ordinary business is to hunt down spiders and drag them off to holes in a sand-pit ; but if she gets a chance she will pillage her neighbours and lay her egg on stolen prey.

The victims paralysed by these different huntresses are required for the purpose of feeding their larvæ. Hence the precise nature of the stinging. The prey must be paralysed. It must not be killed, for the larva requires

living food. Nevertheless we find considerable variation. Perfect paralysis is not always secured. Open a cell of *Eumenes conica*. The caterpillars show varying degrees of paralysis ; some can squirm about a little ; others are completely numb. So it is with the spiders in the cells of *Tripoxylon* ; some will be paralysed ; others will be dead. The Peckhams took eleven spiders from the cell of a *Pompilus*.[1] Three were dead : the remainder lived for variable periods, some four days, another five days, another twenty-three days, another forty days.

An instinct of certain species of *Pompilus* is to cut off the legs of their spiders, probably in order to make them smaller and so get more of them into the nest. But the Peckhams point out its variability.[2] Out of ten spiders stung by *Pompilus fuscipennis* four had not lost any legs, the others had one or two cut off. An analogous habit was noticed by Ferton in a cricket-huntress, *Notogonia pompiliformis*.[3] This wasp cuts off the hind legs of her crickets, I suppose to prevent their kicking, if paralysis is not complete. But in this again we have variation. Seven crickets were taken from the cell of one wasp ; four had the left hind leg gone ; two had the right hind leg gone ; one had all legs complete.

Another way in which we see variation is in the number of victims stored. I have opened many cells of *Eumenes conica*. One may contain four caterpillars, another eight, another ten. Four crickets is the rule for *Sphex flavipennis*. But cells often contain two or three. Mr. Field explored the cells of *Sceliphron coromandelicum*.[4] One cell had three spiders, another had eleven spiders, a third as many as ninety-eight !

[1] *Wasps, Social and Solitary*, p. 216.
[2] *Ibid.*, p. 220.
[3] *Annales de la Société Entomologique de France*, Vol. LXXIV, p. 68.
[4] *Journ. Bombay Nat. Hist. Soc.*, Vol. XXIII, p. 378.

Few instincts are more firmly fixed than that of the prey captured by these wasps. They stick to one particular species, chase it, and it alone. Yet we find variation even in this. *Sphex flavipennis* hunts a species of grasshopper, yet on one occasion she was seen with a cricket. *Sphex occitanicus*, according to Fabre, is strictly faithful to Eppiphigers ; but the fact is that her instinct varies, for she sometimes captures common green grasshoppers. *Ammophila hirsuta* is a better instance. This wasp is a huntress of underground caterpillars. She sticks rigidly to one species, and digs into the earth to get it. But Ferton saw her capturing above-ground caterpillars belonging to two quite different genera. So here we have variation not only in the prey, but also in the method employed to find it.

Of these wasps' many and remarkable instincts there is none more sternly rigid than the spots at which they fix their eggs. Each species hunts her particular victim and fixes her egg to that victim at one very precise spot. *Sphex lobatus*, for example, hunts a cricket, and always puts her egg on the cricket's breast exactly between the first pair of legs. *Ampulex assimilis* hunts a cockroach and never fails to attach her egg on the outside of the cockroach's middle thigh. The object behind all this is safety. It is one of those instincts of vital importance. The egg fixed on the cricket's breast is anchored in a deep recess and cannot be injured if the cricket moves. The egg fixed on the cockroach's femur is sheltered by the overhanging thorax, as it were tucked beneath the edge of a roof.

But even in this rigid life-preserving instinct variations have been observed. Ferton again is the chief recorder. He opened two nests of *Sphex maxillosus*.[1] In one the

[1] *Annales de la Société Entomologique de France*, Vol. LXXIV, p. 64.

egg was fixed to the grasshopper in the space between its front pair of legs ; in the other the egg was on the front of the thorax between the first pair and second pair of legs. He found something similar with *Pseudagenia carbonaria*,[1] a wasp that collects spiders. Both times the egg was on the spider's abdomen, but on one occasion it was on the dorsal surface, on the other occasion on the right side. The only instance of variation that I have met with was on the cockroach captured by *Ampulex assimilis*.[2] The egg was always fixed to the middle of its femur, but sometimes on the right side and sometimes on the left.

Another very exact instinct is that possessed by mason-wasps of putting one egg in each mud cell. Yet here again there is sometimes variation. *Eumenes conica* builds many a cell which never receives an egg. More remarkable still, I have seen this wasp lay three eggs in the same cell. Ferton had a similar experience in Algeria. He found two eggs in the nest of an *Ammophila*, and both an egg and a young larva in a nest of *Sphex maxillosus*. Another observation comes from New Britain,[3] where a social wasp of the genus *Polistes*, instead of putting one egg, introduced several, into each of the hexagonal cells of her comb. Such occurrences are extremely exceptional. One egg in one cell is a particularly rigid rule.

The closing of the nest is an interesting instinct and supplies some good examples of variation. It is best shown by the *Ammophilæ*. Take, for instance, *Psammophila tydei*. Different individuals of this species show clearly individual behaviour. One will close the hole by just kicking in dust ; another will bring pebbles and

[1] *Annales de la Société Entomologique de France*, Vol. LXXX, p. 389.

[2] *Nature at the Desert's Edge*, p. 47.

[3] Willey, *Zoological Results*, Part IV, p. 388.

fix them in the burrow; another will pay little attention to appearances and just make the surface a little smooth; still another will spend a long time concealing it and will end by fetching in a bit of leaf and putting it directly over the nest. *Philanthus triangulum* varies even more. This wasp catches bees and stores them in burrows. When the burrow is in a sand-bank the wasp closes the entrance before setting out to hunt for prey, but if the nest is situated on a wall, then the wasp neglects the closing of the door.

The sites which mason-wasps select for their nests give further proof of variability in instinct. Many wasps nest in Indian bungalows. This in itself shows that instinct has varied. These wasps were originally jungle-haunting insects that nested in hollow trees. Now they enter human habitations and nest on walls, window-sills and doors. *Rhynchium nitidulum* is one of these species which retains a trace of the tree-hollow instinct. She comes fearlessly into rooms, but will not fix her nest anywhere except to a beam of wood. She will not nest on stone and plaster like the others. Enough of the hollow-tree instinct is left to make her seek out wood. *Chalicodoma rufitarsis* varies greatly in her nesting-site. One is sociable, joins a great colony and nests under the tiles of a roof; another is of a solitary disposition and nests in a lock or in the end of a water-pipe; another makes her nest on a stone in the open; another on the bark of a tree; another even wraps it round a stalk. An *Osmia*, which likes to nest amongst heaps of stones, will, if these are not available, establish herself in a snail-shell. Wasps belonging to the genus *Odynerus* originally made tunnels in sand and wood. Now they nest in the oddest places, such as door-locks or rifle-barrels or the cells of other bees. Dr. Marshall mentions a mason-wasp of South-East Africa which not only makes the

usual external mud cell, but also bores nesting-holes in walls.[1]

The way bees seize on the homes of other animals must be attributed to variability. Humble-bees ordinarily choose holes in the ground or gather moss to build their nests with. But I have seen one of our British species occupy the deserted nest of a wren. And *Bombus pensylvanicus*, an American species, has established itself in the nest of a sparrow.[2] Indeed, in America they have gone one better; for humble-bees have there entered a house and made their nest in a box of clothing which had been put away for rags.

The style of nest built by mason-wasps is, like everything else, subject to variation. *Sceliphron deforme* is an Indian species which builds a number of mud cells. The usual arrangement is to place them horizontally; less often she puts them in a vertical line; very rarely she piles them one on top of the other.[3] *Anthophora crinipes* nests in holes. Sometimes she prolongs the hole into a chimney; at other times, for no reason that we know of, she omits completely this piece of work.

These points refer to the appearance of the nests. But when we come to examine the interior we find again that variation is the rule. The best illustration I can give of this is the case of those bees which partition their chambers. A European species, *Prosopis confusa*, nests in the hollow stems of brambles. Inside the stem it makes a string of cells separated from each other by partitions of pith. The point of interest lies in the partitions. One must regard them as important structures, yet we have it on Ferton's high authority that one bee will put her cells end to end without a trace of

[1] *The Zoologist*, 1898, p. 30.
[2] *Entomological News*, Vol. XXIX, p. 114.
[3] *Journ. Bombay Nat. Hist. Soc.*, Vol. XXVIII, p. 295.

any partition, while another individual will separate her cells with distinct walls of pith.[1]

Then again we have the nests of *Osmia cyanoxantha*. This bee occurs in Provence, where it nests in crevices of rocks. The nest is often a single cell, but sometimes the bee builds three or four. On the latter occasion the cells must be separated. This is done by partitions of vegetable paste, which partitions the bee strengthens by incorporating in them small stones. But this stone-strengthening habit is highly variable. The stones may be many or they may be few. In one nest a partition had three layers of pebbles; in another there were no pebbles, nothing but the vegetable paste![2]

The plan on which these wasps feed their young is peculiarly unchanging and exact. *Eumenes*, for example, provisions in bulk. Having laid her egg, she stuffs the cell with provisions, then seals the door. *Bembex*, on the other hand, provisions gradually. While the larva is growing the mother keeps feeding it, just as a bird keeps feeding her young. But *Eumenes tinctor*, an African species, varies her act according to season. In the hot season, when caterpillars are abundant, she provisions in bulk according to rule. In the dry months she waits for the egg to hatch, then brings a supply of food, and later on a supplementary supply before closing the cell. *Eumenes*, in her variation, therefore, approaches somewhat towards *Bembex*.

Turn for a moment to the leaf-cutting bees. They cut pieces out of leaves, sometimes ovals, sometimes circles. With these they line a tunnel and close the entrance with a lid. Examine a series of nests from one species.

[1] *Annales de la Société Entomologique de France*, Vol. LXXVIII, p. 404.

[2] *Annales de la Société Entomologique de France*, Vol. LXXXIII, p. 89.

Variability will be evident in every direction, in the number of the cells, in the number of the leaves, in the thickness of the covering lid. Fabre gives figures for *Megachile albocincta*. A nest usually has five or six cells, but there may be as many as twelve in the string. The number of ovals to each cell varies; they average round about eight or ten.[1]

As I have said, when the nest is finished the bee puts on it some kind of a lid. The plan adopted by *Megachile picicornis* is to use a varied assortment of materials. First she stuffs in some round bits of leaves, on top of these goes a layer of earth, on top of that a plug of clay moistened with a secretion of saliva. This threefold combination makes an excellent stopper. But we find that the stopper varies with respect to each of its three layers. Sometimes the bee neglects to put in leaves; at other times she makes no layer of earth; at other times she forgets the clay and saliva. It is not that the materials are wanting. The bee will neglect to perfect her stopper though the necessary materials exist in the neighbourhood. We cannot account for it in that simple way. All we can say is that the instinct has varied. We cannot explain why.[2]

Certain wasps of the genus *Osmia* have the habit of lining their nests with flower petals. Moreover, each species has her special plant. *Osmia papaveris* sticks to Corn Poppy; *Osmia perezi* to Morning Glory. But when a drought prevented the appearance of the Poppy, Ferton saw *papaveris* get her petals from Convolvulus; on another occasion he saw *perezi* substitute Mallow for Morning Glory.

The way insects make use of exotic leaves shows that

[1] *Bramble-Bees and Others*, p. 260.

[2] *Annales de la Société Entomologique de France*, Vol. LXXXIII, p. 96.

the original instinct must have varied. Leaf-cutting bees will cut their pieces from certain plants introduced from the tropics. It is well known that hive-bees visit strange flowers of which they could never have had any experience. Also Fabre observed that the Cotton-Bees of France gleaned their wool from a plant introduced from Palestine.[1] It is clear that their instinct must have varied somewhat from that possessed by their ancestors.

The making use of altogether unnatural materials is another clear proof of instinctive variation. *Anthidium laterale* is a French bee which makes a nest of resin gathered from cypress trees. But Ferton saw one near a railway station collecting grease from lubricating machines.[2] The same occurs in the *Trigonæ*, stingless bees that live in communities, and secrete wax for their nests and honey-pots. Wheeler particularly observed them in America.[3] He saw one kind collecting crude oil, another kind visiting latrines for excrement, in order to mix these materials with their wax. There must have been considerable variation from the natural pure-wax instinct of the bees. Even honey-bees will collect unnatural materials. They have been known to use wax and turpentine instead of the customary propolis.

An interesting variation of the same class is recorded from the social wasps. These insects make their combs of papery material obtained from fibres of wood. They may often be seen on doors and posts tearing away the shreds and fibres and grinding them up into a papery pulp. But one species in America, *Polistes rubiginosus*, varies in a way that must be highly advantageous.

[1] *Bramble-Bees and Others*, p. 310.

[2] *Annales de la Société Entomologique de France*, Vol. LXXXIII, p. 99.

[3] *Psyche*, Vol. XX, pp. 3–7.

Instead of grinding fibres from posts it sometimes gets its stuff from the paper bags used for storing grapes in the vineyards.[1] This must have been an important discovery. The wasp gets its paper first hand instead of having to manufacture it from wood.

Examples from Ants

An ant community has three types of individual—the queens, the males, the neuter workers. The instinct of the queen is to lay eggs. As a rule the workers are sexless and attend to the duties of the nest. Yet the workers sometimes will lay eggs, though such eggs always develop into males. On the other hand, queens, in extraordinary circumstances, have been known to forage in the same way as workers. Here we have variation in what we must regard as instincts of the first importance.

The instinct of the queen, after fertilization, is to get into the ground, lay some eggs, bring up a few workers which will begin to construct a nest. She then becomes a kind of egg-laying machine. But rob the queen of her first brood of workers. She will not lapse into the egg-laying business. On the contrary, she will start all over again, and proceed to bring up a second brood.[2] Thus we have instinct varying tremendously in accordance with whether she is robbed or not.

The nests of ants show so much variation that it would be tedious to give all my examples. I will mention a few observed in India. *Camponotus compressus* nests in the soil, but if the earth is unsuitable it will bore into a tree. *Œcophylla smaragdina* makes sheds in trees by drawing leaves together and uniting them with silk.

[1] *Insect Life*, Vol. IV, p. 192.
[2] *Social Life among the Insects*, p. 163.

But if the leaves are placed inconveniently then the ants will make their shed exclusively of silk.

Polyrhachis simplex is peculiarly adaptable. Sometimes it digs a tunnel in the ground; at other times it builds a nest in the trees. On these latter occasions we see much variation. The nest is usually wrapped around a branch, but sometimes it is hung like a flat purse, or it may be suspended like a globe from a twig. Then these ants may steal other creatures' habitations.[1] I have seen them making use of a spider's chamber, and establishing themselves in a bird's nest. Then they vary greatly in the stuff they build with. As a rule they collect a variety of fragments, bits of stick and leaf and grass, and these they weave together with silk. But at times they neglect this assortment of materials and make the nest out of vegetable plumes. I once gave them coloured pieces of wool—red bits, blue bits, white bits, and others. This was new material for the ants, yet they took it and wove it into their nest. It reminds one of the humble-bees described by Kirby and Spence, which tore up linen and used its shreds in place of the accustomed moss.

Similar variation, if we look for it carefully, can be found everywhere in ant communities. The English wood ant, *Formica rufa*, builds the well-known mound-shaped nest. The process is one of accumulation. Pine-needles, sticks, leaves and other things are piled into a large heap. But the instinct is so remarkably variable that the method of accumulation may change into burrowing. For the wood-ant has been known to dispense with a mound, and to make its nest by digging into stumps and carving out chambers in solid wood.[2]

Lasius acerborum, according to Forel, never nests

[1] *A Naturalist in Hindustan*, p. 124.
[2] *British Ants*, by Donisthorpe, p. 251.

under stones on the plains of Europe. But in the Alps it frequently does so in the same way as other mountain species.[1] We have a parallel to this in England. The nesting-site chosen by *Leptothorax acervorum* is underneath the bark of tree-stumps; but when we go to the Scotch mountains we find that it gets underneath stones. Another British species, *Donisthorpea nigra*, seems even more plastic at nest architecture.[2] When it nests in tree-trunks it digs galleries in the wood; when it nests under stones it builds earthen cells between the stone and the ground underneath.

Ant slavery is a wonderful instinct. *Formica sanguinea* enslaves an allied species. The slaves are kept indoors and do the household work of the nest. But Lord Avebury tells us that this instinct is variable, that the masters are able to do for themselves, and sometimes occupy a nest which has not a single slave.[3] Indeed, the very fact that ants can be enslaved makes me think that the instincts of the slaves must be plastic. The master's nest and the slaves' nest can scarcely be identical, yet the slaves can adapt themselves to either according as they happen to get enslaved or not.

That same capacity for adaptability is shown in those cases where hostile species manage in the end to become friends. Forel quotes a good illustration.[4] *Formica pratensis* and *Formica sanguinea* are species which ordinarily attack one another. When the ants of one nest are overturned on the other nest, the result is war and pillage. One year Forel emptied some bags of *pratensis* close to some nests of *sanguinea*. He saw what he expected, battle and carnage. But what was his surprise

[1] *Mental Evolution in Animals*, by Romanes, p. 245.
[2] *British Ants*, by Donisthorpe, pp. 202, 203.
[3] *Ants, Bees and Wasps*, p. 80.
[4] *Le Monde Social des Fourmis*, Vol. IV, p. 9.

on the following year when he found the two species mingled together in perfect friendship on the same nest. He could scarcely believe his eyes when he saw them running amongst one another, helping one another to repair the nest and attend to the common brood. It is clear that their instincts must be very variable. In the first place, ants, which are naturally enemies, must be plastic enough to change into friends. In the second place there must be some adaptability when *sanguinea* adjusts itself to the nest of another species, *pratensis*.

When we watch the general habits of ants we continually meet with that variability which refutes the adverse conclusions of Fabre. Take the instinct of gathering food. I have often watched the Indian harvesters. Their business in life is to gather seeds which they store inside the nest. *Messor barbarus* is a good example of the way in which the harvesting instinct varies. For example, the hours of collecting vary in accordance with both country and climate. In the Himalaya at 4,000 feet I have watched them toiling throughout the day; on the other hand, in the Arabian desert they worked only in the mornings and evenings. The same ant lives on the Mediterranean seaboard. There they work most eagerly at midday, while in Eritrea they come out only after sunset. Also they differ in France and Algeria. On the French side they harvest chiefly in Autumn: on the Algerian side mainly in Spring. A better example is quoted by Forel with respect to *Tetramorium cæspitum*.[1] In Britain this ant does not go in for harvesting. It is carnivorous and keeps aphids. But in Algeria it regularly harvests and fills large granaries with seeds.

A habit possessed by many ants is that of closing the nest-entrance at night. *Myrmecocystus setipes* does it,[2]

[1] *Le Monde Social des Fourmis*, Vol. IV, p. 44.
[2] *A Naturalist in Himalaya*, p. 47.

and in India I have often watched them at the task. The usual method is for one ant to do it. A solitary individual gets pebbles outside, stuffs them into the nest entrance, leaving open only a narrow chink. It then squeezes itself through the chink and completes the barrier from the inside. But this little act permits of much variation. Sometimes not one ant but several engage in it. At other times instead of carrying pebbles from the outside, the ant will tear earth from inside the galleries and do all the closing from within.

We can think of few more important instincts than that of spinning a cocoon. The larvæ of many ants do spin cocoons, wrappings which protect them, and enclose them completely throughout the pupal stage. Other species spin no cocoons. The pupa remains permanently naked. But what can we say of a particular species which may or may not spin a cocoon? Yet such occurs with *Formica picea*, a British ant which nests in bogs.[1] Its nest is made of bits of sphagnum, and is filled with moisture like a saturated sponge. Of all imaginable types of nests, it is one of this kind, soaked with water, that should have its pupæ sheltered in cocoons. Yet we are told that the instinct is variable. Some of the pupæ have the cocoon, while other individuals have not.

Examples from other Insects

I will add just a few illustrations from other Orders of insects.

Every one has seen butterflies paired. As they fly through the air one does the flying and carries the other which hangs on underneath. Now it is a rule that, on such occasions, one sex always carries the other. For instance, when two small Cabbage Whites unite, it is the

[1] *British Ants*, by Donisthorpe, p. 332.

male which carries the female. On the other hand, when Apollos unite, it is the female which carries the male. Why, of course, we do not know; but the method is constant according to species. Yet here again we find variation, especially among the Fritillaries. With this group the customary habit is for the males to carry the females. Nevertheless, with two species at least, the Dark Green Fritillary and Silver-washed Fritillary, not only do the males carry the females, but sometimes the females carry the males.[1] It is not because the male is helpless or worn that it fails to perform the carrying function. In such cases the males are perfectly strong. All we can say is that the habit has varied.

Caterpillars have their special food-plants. The rule is that they stick to their plants and refuse any other kind of leaf. But some can be got to change their diet. The caterpillars of the Gypsy Moth, for example, will accustom themselves to new food within the course of a single generation. This shows that the sticking-to-the-food-plant-instinct is not always irrevocably fixed.

But we meet with better examples when we examine the cocoon-making instinct. Caterpillars have been known to vary their cocoons in accordance with the places where they construct them. This has been seen with *Limacodes scapha*.[2] Its habit is to make a smooth parchment-like cocoon, but when kept in a box on a layer of sand, it spins sand into the structure which then comes to look like a granulated lump. Professor Poulton gives a remarkable illustration of a change of colour in relation to environment.[3] One of his caterpillars of the Green Silver Lines Moth had begun to spin a cocoon on

[1] *Entomologist's Record*, 1917, p. 16, and 1920, p. 221.
[2] Psyche, Vol. V, p. 54. [3] *Colours of Animals*, p. 145.

an oak leaf. The cocoon at this stage was brown in colour. He removed the caterpillar to a white box. It remained motionless for several hours, then recommenced its cocoon-making business, but this time made a white cocoon. It has even been observed that a cocoon-making caterpillar will sometimes neglect this important duty. The one in question is *Deilephila lineata*.[1] Its habit is to spin a cocoon between leaves, a delicate structure with meshes like a fishing-net. But put it in a box with a layer of earth. It will make its way into the earth and pupate there without any cocoon.

Dung-beetles' instincts undoubtedly vary. Fabre examined nearly a hundred nests of one species, *Onthophagus taurus*.[2] He found "no two precisely alike, as pieces should be that come from the same mould and the same workshop." The size of these beetles' family seems to vary with both space and food. *Copris hispanus* is a good example. Her method is to get beneath a lump of dung and tunnel down into the earth. Then she pulls pieces of dung underground, shapes them into three or four ovoids, in each of which she places an egg. Having done this, she stays indoors, and does not attempt to make another burrow. But rob her of her pellets, and what will she do? Start laying a second batch, and thus double her normal number.

Fabre put her to a stricter test.[3] He kept repeatedly robbing her pellet, and at the same time giving her food. The beetle replied by manufacturing pellets. As each disappeared, the beetle replaced it. This continued for five or six weeks. In the end she had manufactured thirteen ovoids instead of the usual three or four.

[1] Psyche, Vol. IX, p. 8. [2] *The Sacred Beetle*, p. 270.
[3] *Ibid.*, p. 254.

A last illustration from the Order Diptera seems to me of particular interest. A Tabanid Fly, *Hæmatopota litoralis*, frequents hedges of Prickly-Pear in India.[1] It possesses the highly advantageous habit of sitting at the bases of the Prickly-Pear thorns. The instinct is of first importance. At the base of the thorns the insect is safe. A diverging bunch of spines protects it from all but the minutest enemy. But how and when did the instinct develop? The Prickly-Pear was introduced to India at the beginning of the nineteenth century. Before that date there was no Prickly-Pear nor other plant of a like structure. Hence the insects could not then have had the instinct of sitting at the base of the thorns. The habit must have come since the plant was introduced. We have, therefore, not only an example of variability, but also some measure of the time required for a valuable protective habit to get fixed.

The facts I have given are more than sufficient to show the extent of variability in instinct. Variation pervades all departments of Nature. In our study of Instinct it is ever present, an unmistakable and fundamental fact. Indeed, when applied in the strictest sense, it is not in any way inaccurate to state that no two individuals perform an act in exactly the same way. There is always some trace of individual distinction. Each differs in some little way from another as do men in the ordinary acts of life. Instinct is fixed in a broad sense. The general plan, as a rule, is stable; but the details permit of endless variation, though usually in small degrees.

Our chapter, therefore, is dead against automatism. It also conflicts with the view of Fabre that instincts have always been what they are to-day. On the con-

[1] *Records Indian Museum*, Vol. IX, pp. 245, 246.

trary, instincts supply endless material on which Natural Selection can do its work. Everything goes to show that instincts have changed. If so, then we postulate growth and evolution. Each instinct has come from a simpler type. The view fits in better with the scheme of life than to think that they came ready-made "from the universal knowledge in which all things move and have their being."

CHAPTER IX

ERRORS IN INSTINCT

In Nature there is nothing really perfect. This is clearly true for anatomical structure. Even the perfect human eye is still capable of some improvement. But the same is true for instinct also. Though its perfection so often astounds us, yet it can fall into grievous error. Such errors have received very little attention, yet they are certain to be important. We might compare them with those structural abnormalities which often throw light on anatomical problems.

Examples from Wasps

Again we turn first to the Hymenoptera. Bees and wasps often make mistakes. They have been seen visiting flowers on a wall-paper, mistaking them, of course, for the real thing. I have seen wasps catching flies in a tent, and they repeatedly attacked spots on the canvas, obviously mistaking the spots for flies. When *Sphex subfuscatus* hunts grasshoppers, it often searches for them on the wing. And then it darts on all kinds of objects, mistaking them for the coveted grasshopper. Bramble-bees do the same kind of thing. Their business is to nest in snail-shells, and as they search for a suitable shell, they often throw themselves on small stones.

The nest-building instinct shows many an error. *Pelopœus* builds a cell, and, after provisioning it, closes the

entrance with a lid. But she often makes a serious error. The Peckhams saw her closing the entrance without having put in any provisions. *Tripoxylon rubrocinctum* is a spider-collector; and this one stuffed the cell with provisions and then forgot to put on the lid. Ferton quotes a curious error. *Osmia rufohirta* nests in snail-shells. She carries the nest from one place to another, and in order to give her something to grip, she smears the shell with a kind of vegetable paste. This paste she makes by chewing leaves. It is, of course, a very specialized instinct. Yet Ferton noted what must be an error. The bee, instead of using paste, actually covered her shell with honey.

When these wasps put most unusual captures in their nests, I think that they must do so in error. The *Sceliphron* wasps are strict huntresses of spiders. Yet once, in India, I saw *Sceliphron madraspatanum* stuffing her cell with a green caterpillar. Wasps belonging to the genus *Astata* make burrows in the ground which they fill with bugs, but St. Fargeau met with one of these wasps bringing to its tunnel a small cockroach. Of course there is normally some slight variation in the captures taken by hunting-wasps. But these occurrences of caterpillars replacing spiders and of cockroaches replacing bugs cannot be put down to mere variability. The divergence in the instinct is too great. The wasps must surely have made some mistake.

If we watch a colony of digger wasps we are sure to witness some small errors. I recall nests begun and left uncompleted; also wasps, on their return, appearing bewildered because they could not find their own holes. It is the habit of *Bembex* wasps to conceal the doors of their nests with sand each time they go abroad. But the Peckhams met with some that seemed to be forgetful; at any rate, they did not close their doors. Another

nester in holes is *Trypoxylon rubrocinctum*. On returning to the nest it sometimes misses the entrance, and goes into another wasp's nest by mistake. A delightful little error is told by Ashmead. He watched *Gorytes mystaceus*, an American wasp, which captures the insect in the well-known cuckoo-spit.[1] He saw it stinging drops of water, obviously in mistake for the cuckoo-spit's froth.

Examples from Ants

Ants frequently fall into error. The harvesting species collect seeds and store them in granaries within the nest. *Messor barbarus* is the common representative in India, and its seed-collecting instinct is very strong. But it sometimes makes foolish errors. I have seen it taking in bits of grass, which, as a rule, it studiously neglects ; also the pith of Indian-corn stalks which it probably mistook for useful food. I have even seen one trying to get in a stone about the size of one of their seeds. A comrade forced it to drop the burden, but it persisted in returning to the stone, and in the end lodged it in the nest. The Leaf-Cutters of America make similar mistakes. Though these ants always reject grass, yet Bates observed them carrying in grass, which after a while was brought out again. Moggridge notes mistakes in the harvesters of Europe. *Atta barbara* harvests seeds. He threw amongst them some porcelain beads. The ants tried to carry them off. Some succeeded, others failed. In the end all discovered their mistake. Mr. Donisthorpe studied the harvesters of Sicily and examined the nests there of *Messor barbarus*.[2] He found the granaries full of seeds. But they also contained small pebbles and little bits of broken glass.

[1] Psyche, Vol. VII, p. 305.
[2] *The Entomologist's Record*, 1926, p. 162.

Other kinds, besides harvesters, err. The slave-making ants that carry off pupæ often behave rather foolishly. They will sometimes rush off with empty cocoons, though on the journey they discover their error and leave their useless burdens on the road.

I once observed an odd error made by *Pheidole indica*, an ant which drags other insects to its nest.[1] These ants, when they get a capture, swarm around it and march it off. One day I saw them bringing in a caterpillar, and noticed that, not only did they drag their capture, but in addition every pebble or bit of grass which the caterpillar's body happened to touch. As a consequence all kinds of useless objects were being conveyed into the nest. I then moistened some pebbles with insect juices, and these too were carried inside. It was clear that the ants had made an error. Things which had just touched the caterpillar's body were dealt with as if they were valuable food. How strange that such remarkably adaptable insects should make these simple mistakes.

Another error that attracted me in India was the way in which the Black Ant, *Camponotus compressus*, was unable to distinguish between the head and the tail of a large bug which it habitually tends. The bug in question is *Monophlebus Stebbingi*. It is very common on trees in India. Throughout the hot season the ants attend it. All the time they are incessantly stroking it, and the bug, in reply to the strokings, shoots them out a drop of juice. Now the shape of this bug is uniformly oval. Its front and hind ends are very much alike. The hind end, of course, is the one that needs stroking. It is there that the pore exists from which the fluid is shot out. Now the strange thing is that some of these ants cannot differentiate the ends of their bug. Their lives are spent stroking and tending it, yet it is not uncommon

[1] *A Naturalist in Himalaya*, p. 63.

to see a pair of these ants, one stroking the hind end and getting the liquid, the other stroking the front end and receiving nothing in return. Certainly both ends are much alike, but quite sufficient difference exists to prevent the ants making the mistake.

Another way in which instinct falls into error is when certain ants happen to find injured comrades close to their nest. I refer particularly to *Messor barbarus*, the

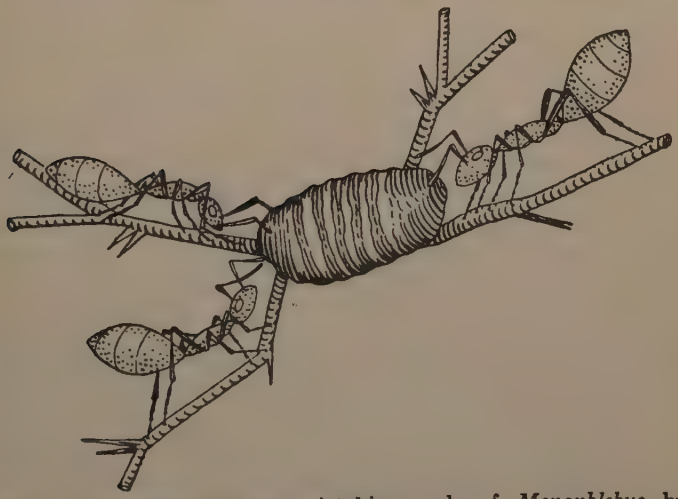

FIG. 13.—*Camponotus* Ants mistaking ends of *Monophlebus* bug.

common seed-collecting ant of India. I have at different times injured some of these ants and placed them close to the nest entrance. Their comrades, on finding them, get very excited. They do not try to help them, as do some other species. On the contrary, they get angry and hostile, and behave in exactly the same way as if an enemy was trying to break in. They dash about in search of the imaginary enemy. Not finding one, they turn their hostility on the injured, and bite them with the utmost resentment and anger. It seems to be a case of instinctive

error. To the ants the presence of an injured comrade implies that some enemy has caused the injury. They seek to discharge their anger on this enemy, but, not finding it, they fall upon their own kin.

An analogous experiment with *Myrmecocystus setipes* produced the same result. In their case I half buried an ant with earth. Its companions found it, attacked it, unearthed it, tore at it with every display of violence, and then dragged it for food into the nest. We cannot but regard this misdirected effort as instinct completely at fault.

Forel observed a similar incident when studying the slave-making ants of Switzerland.[1] *Polyergus* is the ant in question. It keeps in its nest a crowd of slaves, and fights furiously with other ants. When engaged in battle, they get blind with rage. Not only do they assault the enemy, but they bite everything they come in contact with, bits of earth, bits of wood, larvæ, cocoons, even their own companions and their own slaves. So lost do they get in their mad excitement that they can no longer recognize their road. Their slaves try to calm them and direct them, but not till the fury of battle is over can they find their way about like normal ants.

On another occasion he met with *Polyergus* deliberately destroying its own slaves.[2] Now, this does seem very extraordinary. For the ant is absolutely dependent on its slaves. The slaves feed it, tend its larvæ, even build its nest and carry it about. Also the slaves accept their bondage with every sign of passive resignation. In fact, masters and slaves live together in what seems like perpetual peace. Yet here is what Huber witnessed: a complete reversal of ordinary affairs. On one warm day in a *Polyergus* nest the slaves began to get unruly. They

[1] *Le Monde Social des Fourmis*, Vol. IV, p. 141.
[2] *Ibid.*, p. 142.

seized their masters, even bit at them, and dragged them far outside the nest. The masters' bodies were too tough to get injured. Nevertheless, they resented the rebellion. The slaves, after dragging them some distance, released them. But sometimes they continued their vicious bitings. Then the master rose against the slave and killed it by piercing the brain in the same way as it kills its enemies. There must surely be an error somewhere to bring about such abnormal events.

Here is another peculiar error which came under my notice in India.[1] *Camponotus compressus*, the Indian Black Ant, nests at the foot of big trees. This instinct is of essential importance to it. For these ants live mainly on the juices of insects which inhabit the foliage above the nest, and to get which they despatch columns up the trunk of the tree. But if there happens to be a brick wall about, these ants will establish their nest at the foot of it, then send columns up the wall, though of course they find no food. This surely must be an instinctive error on the part of the original foundress of the nest. No doubt the instinct is to make a nest at the foot of some vertical mass. In the jungle such a mass will always be a tree, and this instinct will be a sufficient guide. But away from the jungle there are buildings and walls. Yet the queen, when fixing the nesting site, seems unable to distinguish them from trees. A vertical structure is all she wants. Hence she is led into the mistake.

Examples from other Insects

Butterflies and moths sometimes make mistakes with respect to the flowers they visit. The humming-bird hawk moths seem specially liable. One will come to the artificial flowers sticking out of a lady's hat; another

[1] *A Naturalist in Hindustan*, p. 29.

will try to get its beak into the blooms painted on tapestry.

The flesh-fly, which ordinarily lays its eggs on carrion, is well known to do so on the carrion flower, quite obviously a mistake in instinct. Tachinid flies, which lay eggs on caterpillars, have been seen doing so on a hard-coated beetle, apparently mistaking the bright colour of the beetle for the similarly bright colour of the caterpillar. Mistakes of this kind mean death for the offspring. The larva of the flesh-fly cannot live in the carrion flower, nor can that of the Tachinid penetrate the hard beetle in the way that it eats into the caterpillar.

Butterflies and moths are very strict in laying their eggs on the correct food-plant. The instinct is of vital importance, for the caterpillars die when on the wrong leaves. Nevertheless they sometimes do make mistakes. *Catonia ilia*, a Noctuid moth, ordinarily lays on the burr oak. But its eggs have been found on the chicory, a plant which its caterpillar refuses to eat. The Cream-Spot Tiger Moth errs more grievously. Her method is to place neat batches of eggs on the dock, the groundsel and other low-growing plants. But her eggs have been found on the trunk of a fir tree, and also fixed to a piece of slate. There seems to be little doubt about the fact that it is through the sense of smell that the butterfly recognizes the correct plant. This explains the mistakes they are liable to make when different plants are mingled together. For instance the Swallow-Tail, *Papilio machaon*, is accustomed to lay on the milk parsley; but if other kinds of plants grow close to this food-plant then the butterfly will lay on the other plant by mistake. Under these circumstances it has been seen fixing its eggs to the potato.

When insects pair in an illicit manner I think we must regard it as a kind of error. Take butterflies as an

example. The males often pursue the females. This is certainly legitimate enough. But sometimes they make mistakes about it. A butterfly will dart at the wrong species, or will fly at a feather blown through the air. More curious, however, is the fact that they sometimes make illegitimate unions.[1] For instance, a male of the Meadow Brown has been captured in union with a female Ringlet. Also a female of the Chalk Hill Blue has been taken in union with a male of the Common Blue. Other examples could be given from moths in which different genera have been found to unite. Of course the occurrence is very unusual, for it is one of the strictest laws that unions should take place within the limits of the species. Indeed, this law must be of vital importance. In all likelihood the refusal to cross has preserved many species from complete obliteration. Hence I regard these illicit unions as a kind of mistake in instinct.

Female insects in confinement sometimes eat their eggs. This must be a kind of erring instinct. Earwigs have been seen to do it. I have observed it with a Solifugid. When ants are kept in artificial nests the queens have been seen to eat their own larvæ, also the larvæ to eat the queen's eggs. Is it not an error that induces certain humble-bees to snatch away and devour the eggs as fast as they are deposited by the queen? One must think so, for the queen attacks and drives away the robbers, then hurriedly conceals the egg underneath a covering of wax. A still more vicious example is displayed by *Chrysopa oculata*, one of the delicate lace-wing flies. The females have been seen gripping hold of the eggs and hauling them out of their own abdomens. The operation is performed with their jaws, after which the eggs are rapidly devoured. In all these examples the error is so serious as to be suicidal to the race.

[1] Castle Russel in *The Entomologist's Record*, 1917, p. 212.

Domestication seems always to vitiate instincts. It has succeeded in doing so with the caterpillar of the silk moth. Darwin tells us that these "caterpillars, when placed on a mulberry tree, often commit the strange mistake of devouring the base of the leaf on which they are feeding and consequently fall down." Some, being unable to get back, actually perish of hunger.[1]

The caterpillar of the Emperor Moth ordinarily constructs a bottle-neck cocoon. But Eltringham, who reared a number of these caterpillars, met with one which built a spherical cocoon,[2] without any bottle-neck. In fact, the structure had no egress of any kind, and the moth, as a consequence, could not get out.

Another rather curious instance is that of the moth *Phryganidia californica*, which lays its eggs on Californian oaks.[3] The caterpillars persist through the winter by devouring the oak leaves. Now in California there are two kinds of oaks; one, the liveoak which keeps green through the winter; the other, the deciduous oak, which loses its leaves. The moth, however, cannot distinguish them. When Autumn comes it lays its eggs, scattering them freely over both kinds of oaks. Those that go on the liveoak survive, but the myriad that are laid on the deciduous oaks all perish with the dropping of the leaves.

Certain caterpillars bore into fruits. They eat up the contents of the fruit, pupate inside, change into moths which escape through the boring made by the caterpillar. Now, in order that the sequence should go on without a hitch, the caterpillar must make a hole large enough to allow the exit of the moth. And this, of course, it ordinarily does. In fact, one would think that it knew the reason, for it specially makes a much larger hole

[1] *Variation in Animals and Plants*, p. 372.
[2] *Butterfly Lore*, p. 80.
[3] *Entomological News*, Philadelphia, 1896, p. 174.

than is necessary for its own entrance. Nevertheless it may err fatally. Take the case of the Indian *Heliothis armigera*.[1] This moth attacks the opium poppy. Its caterpillar, when approaching maturity, bores into the poppy capsule. Having got inside, it eats up the contents, and, if the poppy is large with sufficient food, it pupates within the capsule. The moth develops, and now comes the difficulty. In 70 to 90 per cent. of cases the tunnel which the caterpillar made to get in by is not large enough to allow the exit of the moth. Hence the moth remains a prisoner and dies inside the capsule. The final result is enormous destruction because of this error on the part of the caterpillars.

Examples from Spiders

Spiders, though possessed of such exact instincts, sometimes make peculiar mistakes,

When a tuning-fork is sounded close to a spider the creature will sometimes come forward to investigate. It must mistake the sound of the instrument for that of a buzzing insect. Bristowe and Locket refer to the point in connection with *Amaurobius similis*.[2] They vibrated a tuning-fork close to this spider. The spider rushed forth, seized the tuning-fork, " and walked up to it, biting it continually and trying to find a tender spot."

Another little error refers to reproduction. Lycosid spiders, as is well known, anchor their egg-bags to the ends of their abdomens and drag them about wherever they go. But what did Locket once observe ?[3] He happened to meet with *Lycosa palustris* dragging about an empty snail-shell in mistake for the bag of eggs !

[1] *Indian Museum Notes*, Vol. I, p. 99.
[2] *Proc. Zoo. Soc. Lond.*, 1926, p. 336.
[3] *Ibid.*, p. 329.

One error came to my own notice. I was making experiments on a circular web belonging to the species *Araneus nauticus*. A spider had its web half built. I took it from the web, and after a lapse of five minutes, put it back again in the web. I thought that it would go on where it left off, and finish the half-completed web. But what did it do? It first carefully examined the web, then gobbled up the whole structure and commenced to build a new web.

The point which strikes me in so many of these errors is the fatal consequences which they entail. An egg laid on a wrong food-plant means death to the future caterpillar. Illegitimate unions, if persisted in, would bring about death to the species. The moth in the cocoon without a neck died because it could not escape. The eggs laid on deciduous oaks perished because the leaves fell. The moths that developed inside fruits died because the exit holes were too small.

It indicates in the clearest manner the absolute necessity for the strictness of instinct. We must think of the instinct of every creature as filling some crevice in the scheme of life. As each species has its own niche, and as we cannot eliminate one without disturbing the balance of existence, so has every instinct its own setting. It depends on some other occurrence in Nature and some other occurrence is dependent on it. Hence it must work with the strictest accuracy and keep to the confines of its own niche. If it errs, though ever so little, there may be disastrous results.

CHAPTER X

RUDIMENTS OF INTELLIGENCE

We pass from instinct to the sphere of thought. Instinct, we have seen, is the all-powerful force that governs the insect's life. All its main actions are purely instinctive, done because they must be done, the creature knowing neither how nor why. All its chief activities come within this category, its particular method of securing food, the plan it has of avoiding enemies, its devices connected with nests and eggs. All these are plain manifestations of instinct. The insect performs them; it must perform them. They are part of its stock-inheritance. They were born with it, a portion of itself. It has no option but to do what they demand of it, and to do it both in ignorance and blindness.

Is that all? Are these creatures, then, merely automata? Is every action, every movement, every detail of their lives foretold? Do they really act like blind machines, grinding out their busy lives in heedless, thoughtless, sightless rhythm? Some observers would have it so. I think it is because they have happened to concentrate on one of the particularly unadaptable groups. For the first thing we must remember is that the groups of the Arthropoda vary in mentality to the furthest extreme, far more, in my opinion, than do the minds of mammals and birds.

I happen to have been interested in two groups which stand at opposite ends of the scale. Spiders and ants

form two extremes. My attention has fortunately been directed to both. Each possesses instincts of the highest order. There are few things more wonderful than the spider's net, and what can be more elaborate than the instincts of ants! Might not either of these supply good evidence with regard to what is rational in animal behaviour? Not at all. Though I have observed and experimented on spiders of all kinds, though I regard the circular net as the most elaborate of all the achievements of instinct, yet I have met with only one act which suggests intelligent behaviour in spiders. Were I to judge animals by my observations on spiders, I should regard them as almost blind machines. Fortunately ants supply a corrective. Almost equal with spiders in the wonder of their instincts, they act and behave in such a way as sometimes to stagger us with their show of intelligence. One cannot deny them the gift of judgment. Did not Lord Avebury go so far as to rank them in intelligence next to man?

We must, therefore, try to draw our evidence widely. It will not do to lump all insects together. Each group possesses its degree of mentality, some high, some low. Specialization on any one is certain to prejudice our views.

It is this, I think, which has made some observers hesitate to admit intelligence in insects. But the view will not fit every case. Fabre studied the Solitary Wasps, a particularly adaptable and intelligent group. Yet he insists on the blindness of their actions. Again and again he seems to be in doubt. Again and again he records observations which, at least, remove them from the rank of automata. He seems to be struggling against his prejudices. In one very remarkable chapter he writes as if driven almost to contradiction.[1] He admits a kind of rudimentary faculty, yet he fights against the word

[1] *Bramble-Bees and Others*, Chap. VI.

Intelligence. What does he do ? He invents a term. He grants the insect what he calls *Discernment*.

Let us examine this particular point. What is this rudimentary intelligence, the discernment of Henri Fabre ?

Fabre grants the insect a rudimentary discrimination. It can differentiate between one thing and another, of course only between things within the sphere of its particular business. The wasp can distinguish " between the dry and the wet, the solid and the fragile, the sheltered and the exposed." A *Pelopœus*, which ordinarily nests under a stone, can do something better by installing herself in the home of man. A mason-bee, which ordinarily nests under a roof, may, if it suits her, build on a stone, or fix her nest to the bark of an oak, or even wrap it around a stalk. But that is all. That is the limit of the insect's discernment. It is an intelligence scarcely worth bothering about. " Animal resources have a certain elasticity." So much Fabre admits. His elasticity, however, has very narrow limits. It is intelligence of the most rudimentary kind.

We will here consider these glimmerings of rationality. They will show us the possession of something better than instinct, and will serve as a link between blind behaviour and intelligent action of a higher kind.

Examples from Wasps

It is a fair test of rudimentary intelligence if an animal changes its routine behaviour, and by doing so makes a distinct gain. I will give a few examples.

Mason-bees ordinarily build mud nests, a work of elaborate routine. But if they come on a deserted nest, they will sometimes clean it and improve it, an act which suggests some degree of reflection, since it saves them the

labour of building for themselves. Carpenter-bees show the same discernment. These bees drill nesting-holes in trees, a long and laborious piece of work. *Xylocopa violacea* is one of these species, which, though very clever at its drilling operations, will not hesitate to use an old burrow and thus save itself an immensity of toil. It will even go to a hollow stick, and make that serve as a nest.

Wasps, when choosing their nesting sites, act in a way which seems to me as showing a glimmer of reflection and judgment. *Eumenes conica*, the Indian species, prepares the site with the greatest care. She comes into bungalows, may build anywhere, on wood, on plaster, on metal, on glass. She adapts her behaviour according to the nature of the surface chosen. If the surface is smooth, such as metal or glass, the wasp builds without any preparations. If rough or fibrous, as wood often is, she spends a long time tearing at the fibres, and will not build until it is made smooth. Nothing is more clear than that she discriminates. One site needs preparation ; another site does not.

This wasp, I think, is peculiarly adaptable. I have already mentioned her nest, a cluster of oval cupolas of mud fixed by their bases, usually to a wall. Now we frequently notice that the colour of these nests varies with the surface to which they are attached. If fixed, for example, to a beam of wood, the nest is just a brown lump of mud. If fixed, as they often are, to whitewashed walls, then the nest is often streaked with white material which helps to make it blend with the wall. Whatever we may think of the wasp's mentality, such behaviour as this cannot be instinctive. We must admit that there is some discrimination, moreover an advantageous discrimination, in this different behaviour at different sites.

I imagine that perhaps the reader will say: "The argument is all very well, but I doubt if the facts are correctly recorded." Well, the best reply to this objection is to mention another wasp that does the same. For *Eumenes* happens to have a competitor in this art of whitewashing a conspicuous nest. In Ceylon the spider-huntress, *Sceliphron violaceum*, stores her victims in holes in walls. First she lines the cavity with mud, then stuffs it full of spiders, then plugs the hole with clay. Now if the hole is in a mud wall, then all the wasp does is to stick in her plug. But if the hole is in a white-washed wall, then the wasp in addition whitens her plug.[1] Mr. Wickwar, who saw this interesting occurrence, thinks that she must get her whitewashing material from the coverings of scale insects that live on plants. Again I repeat that instinct fails to explain these clearly discriminating acts.

Turn to these wasps at their building operations. Even Fabre describes certain activities to which we must give some degree of judgment. His species is *Eumenes amedei*. Her nest consists of a two-layered structure. First she makes a wall of clay, then covers the wall over with pebbles, all more or less equal in size. Her favourite stones are bits of quartz. She must get suitable pieces. Nothing seems more clear from Fabre's description than that she acts with discrimination and choice. Here is what he writes with respect to the pebbles: "They are selected with minute care. The insect weighs them, so to say, measures them with the compass of its mandibles, and does not accept them until after recognizing in them the requisite qualities of size and hardness."[2]

[1] *Spolia Zeylanica*, Vol. VI, p. 179.
[2] *The Wonders of Instinct*, p. 210.

Here we have a statement from a hostile observer. It seems to me clearly to indicate choice. I would even suggest the same kind of choice as is shown by a man when building a wall.

But to come back to *Eumenes conica*. Here is an incident in her building operations which demands for its explanation rudimentary intelligence. She is building her cell. The work consists in bringing pellet after pellet, spreading them out one above the other so as to form a wall. Each pellet is laid over the preceding pellet, and at each visit is completely used up.

One day I was watching *Eumenes* at work. Pellet after pellet was arriving. The wall was being built according to plan. Now, on one of her visits, for some reason or another, the wasp brought an unusually large pellet. It was so big that she could not properly manipulate it, for the spreading of the mud is a delicate task. The wasp seemed to understand her difficulty. She cut her pellet into two parts. One part she carried to the surface of the cell, searched about for an uneven spot and used up that part in making the unevenness smooth. The other part, which was now of the correct size, she applied to its proper place on the wall.

Such behaviour is quite out of the ordinary. Moreover, it implies some degree of reflection. The wasp seems to show a twofold intelligence: first, in her act of halving the pellet because it happens to be too large; second, in her use of the redundant bit by studiously seeking out an uneven spot in order not to waste her clay.

The way mason-wasps behave when their nests are interfered with shows that they are not blind automata.

I put foreign objects in the nest of *Rhynchium nitidulum*, a builder of clay pots in Indian bungalows. First I try a straw, then a few hairs, then a piece of cotton-wool. The wasp, on her return, sees that something is wrong, and quickly pitches the stuff out. Put some spiders into the cell of a caterpillar-storer, for example *Eumenes conica*. The wasp will not continue blindly provisioning. She will throw out the unsuitable spiders and replace them with suitable caterpillars. Mr. Rau quotes a case which shows better discrimination.[1] He found some nests of *Sceliphron cæmentarium*, a spider-storing wasp of North America. He took some spiders from the cell of one wasp and put them in the half-provisioned cell of another wasp. But the second wasp refused to accept them. Though they were the special kind of spider she wanted, yet she knew in some way that they were not her own, therefore she pitched them out. These acts are not put forward to prove much intelligence, but they show that the creature is able to discriminate, which is all I wish to establish here.

The way some of these wasps evade parasites makes us feel that they have some idea that the parasite is a danger to them. And this implies, at least, discernment. It is only some that appreciate this danger. To many kinds the presence of a parasite means just nothing at all. But *Aphilanthus frigidus*, an American species, acts as if she knew what the parasites were after.[2] This wasp makes a tunnel in the ground and carries ants into the tunnel. The Peckhams saw her engaged in provisioning, and noticed that she was followed by two small flies. These were parasites, whose object, no doubt, was to

[1] *Entomological News*, Nov., 1913, p. 303.
[2] *Wasps, Social and Solitary*, p. 171.

follow the wasp into the tunnel and lay their eggs in her store of ants. But the wasp seemed to understand their intentions. She refused to enter so long as they followed her. She kept circling about and around the nest. In the end she evaded them and slipped inside.

I can give a converse illustration from India, that of a parasite understanding its host. *Eumenes conica*, the builder of mud cupolas, has a dangerous enemy in a blue *Chrysis*. This parasite, a kind of insect-cuckoo, lays her egg in the mason's nest. The egg hatches, and the young *Chrysis* devours the caterpillars stored by the wasp. Now, the *Chrysis* shows something like judgment in watching for the time to get in her egg. *Eumenes* is building: the parasite is watching. *Eumenes* goes away for material; *Chrysis* advances, examines the cell, but withdraws before the owner returns. This goes on in a rhythmical manner; *Chrysis*, at each absence of the owner, making a fresh visit to the cell. At length the time comes when the nest is finished, and then *Chrysis* pops in her egg. Of course the main act is one of instinct, but can we ascribe the details to instinct? Are these visits of inspection merely instinctive? I am certain they contain no little discernment. Each visit, in fact, is a simple judgment as to whether the cell is yet ready for the egg.

The *Osmiæ*, like *Eumenes*, seem very adaptable. I have had little opportunity to test them; but Fabre himself gives some incidents which counter his own rigid views. For instance, he tells how he got *Osmia tricornis* to build her nest in glass tubes.[1] He plugged the ends of these tubes with pith. If the plug of pith happened to be smooth, then the bee immediately set about nest-building.

[1] *The Wonders of Instinct*, pp. 234, 235.

If the plug, on the other hand, happened to be irregular, then the bee first coated it over with mortar before commencing the nest. Also the bee acted differently in accordance with the width of the glass tube. If the tube was narrow, ¼ inch in diameter, the bee set to work bringing pollen and honey to it. If, on the other hand, it was twice as wide, the bee commenced by narrowing the lumen until she brought it to a suitable width. This is surely something better than trivial *discernment*. According to Fabre the insect's highest gift is to discern between one thing and another. It can distinguish "between the dry and the wet, the solid and the fragile, the sheltered and the exposed." And that is about its limit of mentality. It seems to me that his own observations make the creatures out to be better than that.

Turn now to the hunting-wasps. I think it is impossible to watch a *Sphex* with her capture and believe that her innumerable details of behaviour are due to the blind operation of instinct. The main essential stages of the act—the paralysing, the dragging, the burying of the victim—are clear manifestations of powerful instinct. But within the sphere of that instinctive action are a myriad of minor adjustments which necessitate, at least, a minute degree of judgment. Moreover we see much individual variation, I mean, of course, within the same species. One is clever, another is foolish. They have different degrees of adaptability in the way they get their victims along. There is variation in the details of behaviour at least as marked as variation in structure. Other observers have noted the same. The Peckhams have seen "degrees of intelligence" amongst Pompilids. Lubbock mentions similar differences amongst bees. And not merely variations in instinct. The Peckhams par-

ticularly refer to variations in "character and intellect."

Take, for instance, the way a *Sphex* gets her victim past a series of obstacles. We see her for a time getting on smoothly, then she has to back out of a grassy tuft, then make a diversion to get round a stone; then, if opposed by an unsurmountable wall, she makes what is clearly a flight of inspection, comes back to where she left her victim and hauls it along an easier route. There is an Australian species, *Diamma bicolor*, which, when her victim gets entangled in grass, leaves it for a moment, bites away whatever obstructs it, makes an open fairway ahead, and then resumes the pulling of the load. These little incidents make us believe that there is a glimmer of appreciation running through the act of instinct, that the wasp, far from acting blindly, is able to recognize means and ends.

The way in which a *Sphex* buries her victim seems to suggest some glimmerings of thought. Some, like *Sphex lobatus* in India, just shuffle back the sand indiscriminately. They happen to work in loose soil, and all they need do is kick back the dust. But those species which work on rougher ground must make themselves more adaptable. Then, in addition to sweeping back dust, the wasp will search around for suitable pebbles and employ them to strengthen the plug. Nor does she take up any pebble that offers. She may go a little distance for them, searching and selecting. Indeed, even Fabre admits that "she seems to choose them conscientiously as a mason would choose the chief stones of his building." That is a pretty big admission from one who would grant only *discernment*.

Examples from Ants

I have said that the detailed observation of a *Sphex* will force us to admit that a ray of intelligence streams through the instinctive act. It is exactly the same with ants. Take the Indian species, *Polyrhachis simplex*, employed at building a nest.[1] The nest is composed of fragments of débris stitched together with silk. It is fixed to the branch of a tree. Now, I watched one being made by sixteen individuals. Six of them were bringing materials, running up and down the tree, fetching stuff from the ground underneath. One had a bit of clay, a second a straw, a third a twig, a fourth a seed of grass, a fifth a piece of shell. These same six that brought the materials arranged them in the wall of the nest. They did not just push them in anyhow. They acted designedly, I believe with judgment. They chose the best spot in which to put each brick, often wandering all round the nest before finding the most suitable place. The impulse to build was of course instinctive, but a gleam of intelligent choice and adaptation streamed through the whole act. In addition to the six there were two others which did not fetch materials but remained on the nest. They moved about on the nest wall, fitting and adjusting the twigs and straws which the six carriers had brought up the tree. In the interior were six others. I could not see well what they were at, but have little doubt that they were smoothening and adjusting the inner surface of the nest wall. Then there were two others engaged in stitching. And this is the most marvellous of their varied acts. Each held a larva in its jaws. It moved the larva from place to place, made it touch the nest materials at different spots, and the larva at each touch anchored a thread of

[1] *A Naturalist in Hindustan*, p. 98.

silk. This was the *Polyrhachis* plan of binding the nest materials with silk.

If we ponder for a moment over this scene, on such points as the way in which the labour is divided, the

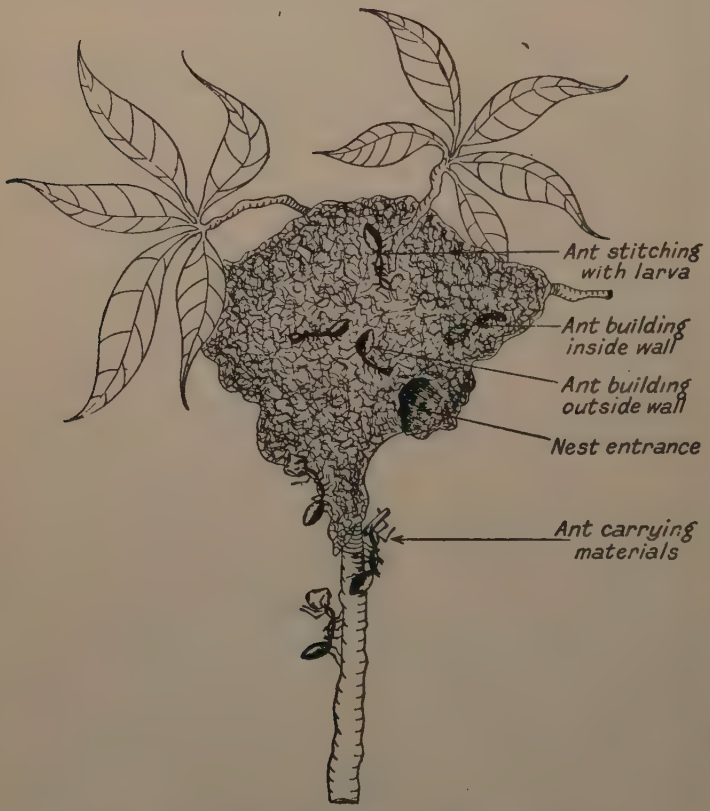

FIG. 14.—*Polyrhachis* ants building nest.

choosing of suitable places for each brick, the fitting of each fragment into its niche, the smoothening out of places where the surface is uneven, we cannot regard it as a

blind operation, but must admit that some gleam of judgment runs through the whole task.

Ants appear to be more adaptable than bees. Their nests are not made on so strict a model as are the combs of hive-bees and social wasps. Forel has particularly noted this point, and remarks on the absence of an unchangeable model. He even goes so far as to maintain that they can suit their "little perfect work to circumstances and take advantage of each situation." This would seem to be quite sufficient to fulfil the requirements of rudimentary intelligence.

Indeed, we cannot watch ants at the business of their nests without meeting with instances in their behaviour that demand something more than instinct for their explanation. *Messor barbarus*, the Indian harvester of seeds, is a species poor in mental capacity. Yet we see points in its behaviour which imply some trace of judgment. Block the door of the nest with pebbles at a time when the ants are fetching seeds. The laden ants arrive at the door. Finding it closed, what do they do? They begin by laying down their burdens, then drag away the pebbles from the entrance, then return to their loads and carry them into the nest. The modification in behaviour is to overcome a difficulty. It is scarcely possible not to believe that the ants appreciated what they had done.

MacCook made a similar observation with respect to the American harvesters.[1] A flight of Termites happened to be abroad. The ants were collecting them in thousands, so much so that the nest got blocked with their

[1] Quoted in *Animal Intelligence*, by Romanes, p. 109.

bodies and the ants could not get their captures through the gate. What did they do? Not just struggle vainly to get in, as they certainly would have done, had they been mere automata. On the contrary, the ants piled their captures in a heap, a good handful at one side of the entrance, then went off to capture more. Here again we have discernment. The ants were able to adapt themselves to an unexpected state of affairs.

Messor barbarus, we have seen, interrupted her task in order to take up something quite different. It gave up gathering seeds in order to pull pebbles from the gate. Surely behaviour of such a kind cannot fit in with unconscious instinct. It may be well to give another example. Here is one from the slave-making species.[1] These ants on their raiding expeditions often have trouble in finding their way home. They may be observed to come to a halt, not knowing for the time which road to take. Then we see them do a decided act. They lay down their loads, run about until they find which road they should follow, then return to where they left their loads, pick them up and march away. Here again we have an act which shows at least the glimmerings of judgment.

Ants gathering food and making captures must meet with so many unexpected contingencies that they could not get through them without some discernment. See a harvester bringing large seeds. Can anyone believe that its actions are blind, just those of some mechanical seed-collecting apparatus? On the contrary, the insect shows some little judgment in the way it catches the seed, first

[1] *Animal Intelligence*, p. 71.

at one point, then at another point, testing it all round in different directions before rejecting it as an unsuitable load. Moreover, we see individual variability. One is clever, another is foolish in finding out the way to manipulate its burden.

Camponotus compressus, a large Indian Black Ant, persistently tends a big white bug known to science as *Monophlebus Stebbingi*.[1] The bug sits on a green stem with its beak in the tree sucking out sap. The ant comes behind it and gently strokes it. The bug in reply shoots out a drop of fluid which the ant sips up. Thus the sap which the bug sucks from the stem is given out as fluid to the ant. But here is the particular point which struck me, the point which I regard as an act of discernment. The ant appears to appreciate the fact that the bug can supply fluid only when its beak is stuck in the stem. For when the bug begins to move about, the ant ceases to bother about it. And though its movements are extremely slow, nevertheless the ant refuses to stroke it unless its beak is buried in the stem.

I will not be tedious in enumerating examples. An observer of ant life meets with many incidents in which these insects adapt their behaviour to what we must call an appreciation of circumstances. Here are a few which particularly struck me. Ants, that transport heavy loads, will keep gathering round the load until it is got moving, after which more will refuse to join in. Ants, that call out comrades to help in a capture, will keep on bringing them until the prey is overwhelmed, then they will bring no more. *Œcophylla smaragdina* exemplifies the first;

[1] *A Naturalist in Hindustan*, p. 29.

Pheidole indica the second of these points. What do we think of them ? If we do not wish to grant much judgment, at least we must give to such actions the little that Fabre includes in *Discernment*.

Not only do I see some intelligence in these acts, but I have no doubt that the capacity varies in different individuals of the same species. Lord Avebury, the highest authority, states that an ant which, when alone, will run away in an emergency, will defend itself when supported by friends. It reminds me of experiences with *Anthophora* bees. These are fluffy insects which live in communities. When solitary, they refrain from attack ; but if the whole community is interfered with, it attacks in a dense swarm. We cannot explain this by instinct. Instinct would impel the insect to attack, quite indifferent to the point of view as to whether an attack was prudent or not.

Examples from Beetles

Those beetles that roll pellets of dung certainly possess what Fabre calls *Discernment*. Here we are concerned only with these glimmerings. Later we will see them doing better things.

A beetle, whose business is to mould a pellet, must have some little spark of thought when it rolls away the round droppings of a sheep instead of making a ball for itself. But it is when watching these creatures at work that we see that same capacity to differentiate which the Peckhams demanded for their solitary wasps. For the Peckhams were quite certain that their wasps " show not only instinctive acts, but acts of intelligence as well." So it is with these active dung-rollers.

I refer to *Gymnopleurus miliaris* of India. A pair of these insects make a pellet out of dung and roll it over

the ground. The operation, in the main, is, of course, instinctive, yet running through it are innumerable little acts which we must ascribe to discernment. Here, for instance, are a few examples. The beetle will prefer a bit of dry dung to soft dung ; it will start its ball-making round an excrescence in preference to the smooth surface of the mass ; it will get its ball away peacefully if it can, if not it will fight to retain its prize. These, and innumerable other adjustments, are at least as good as what Fabre grants the insect, the capacity to distinguish " between the dry and the wet, the solid and the fragile, the sheltered and the exposed," his necessary qualifications for the possession of Discernment.

But it is when their balls meet with obstacles that we see the little gleams of judgment shine forth. Their ball strikes up against a clod of earth. After vainly attempting to hoist it over, one of the pair goes off to explore. Without the slightest doubt it examines the obstruction, then comes back and makes another attempt. Sometimes they meet with another class of trouble. They have happened to make their ball too big, or the rolling has pressed it out of shape. What do they do ? Not, like automata, continue their blind rolling. They smooth it if it is too rough, remould it if it is unshapely, even cut off a redundant bit if it happens to be too large.

Then the time comes when they must bury it. Usually the ball goes easily into the burrow. But if it does not enter, the beetles turn it about. Another diameter may fit the hole better. If this fails, the beetles will enlarge the entrance until the ball manages to fit in.

When the ball is rolling I make a few experiments. I cut it in half. A terrible catastrophe ! The beetles examine it, survey the two hemispheres. Then they gather the halves together, and press them again into a ball. I cut the ball into four quarters. A still bigger

catastrophe! The beetles mould them together again. I alter the shape of their perfect sphere, make one into a cube, flatten another into a disc. It is marvellous to see the beetles' appreciation. I cannot here go into all the details, but they turn both my cube and disc back into the perfect sphere.[1]

I need not go into further details. All the little incidents that I have mentioned cannot be explained on

FIG. 15.—*Gymnopleurus* repairing bisected ball.

blind automatism. Grant the insect, at the very least, that glimmer which Fabre has called Discernment.

I have made many experiments on these beetles. One of the most consistent things about them is the way in which the beetles examine and inspect when anything goes wrong with their work. Even Fabre admits this in some of his observations. The Elephant beetle, which lays eggs in an acorn, takes the greatest care to determine that no other beetle has been there before it. It "*investigates* the acorn at close quarters, is often obliged to

[1] Full details in *A Naturalist in Hindustan*, p. 251.

scrutinize practically the entire surface before detecting the telltale spot." The *Necrophori* beetles, which bury corpses, have slow work in getting them underground. From underneath they thrust up the earth, but, from time to time, have to come out in order to take stock of the progress made. One of them emerges, investigates the dead animal. "He hurriedly returns, appears again, once more *investigates* and creeps back under the corpse." Fabre strapped a dead mole to a stake so that the beetles could not get it underground. One of them ascends, "wanders over the mole, *inspects* him, and ends by *perceiving* the strap."

These different quotations are taken from Fabre. And what, I ask, do they imply? What is this investigating, scrutinizing, perceiving, if not the little gleam of judgment illuminating the instinctive act?

It is not necessary to give more examples. But we must ask: "What is this discernment?" Surely if it means anything at all, it means something like selection and choice. Even the little that Fabre allows, "the dry from the wet, the solid from the fragile, the sheltered from the exposed," to differentiate between those implies some kind of preference, though admittedly of the most rudimentary kind.

All that I wish to prove in this chapter is the existence of that preference, call it discernment or anything else. For that faculty which Fabre calls *Discernment* is nothing else but a simple intelligence. We gave it as a test of rudimentary intelligence that an animal should change its routine behaviour in order to make a distinct gain. That to our mind cannot be instinctive. It must imply some act of choice. In this chapter we have given innumerable examples. To my mind they indicate some

thinking power, some dim realization of the work to be performed, some capacity to adapt means to ends. And that dim realization operates everywhere throughout the insect's life.

Instinct is exactly what we have described it. It means nothing but blindness and ignorance. It is the mainspring of the insect's life, the force that governs its routine actions, the psychic sea in which it lives. But running through it, illuminating it, breaking all over it, like ripples on a great ocean, are endless little gleams of reason.

CHAPTER XI

INTELLIGENCE IN ANTS

We have arrived at this conclusion. The insect is not a blind automaton. There is a ray of conscious thought running through its whole life.

This view, I fear, will meet with opposition. To Bethe the insect is a thoughtless automaton ; to Loeb it is only another kind of plant ; to Lefroy it is a machine without emotion ; to Fabre it is just a shade over the mechanical, possessed of a something which he calls *Discernment*, yet, withal, an extreme conservative, " learning nothing, forgetting nothing," and without the slightest gleam of reason.

It is necessary, therefore, to establish our position, and demonstrate Intelligence in insect life.

We begin with the ants.

Their Intelligence as Excavators

The ordinary plan of excavation is for ants to carry out earth and pitch it outside the nest. There is nothing particular to note about it. All the ants engaged at the task behave in the same way.

But now and again we meet with an incident where the ants behave in an unusual manner and in doing so show remarkable judgment.

For instance, *Messor barbarus*, the Indian harvester, digs its nest on the ordinary plan. But one day I met

with a deviation. Nine ants were making a nest which was situated on a slope. The earth which they brought out was piled into a heap, flat on top but precipitous in front. Of the nine ants, eight were diggers. These eight carried out the earth and laid it on the flat top of the heap. The ninth ant behaved differently. It never went into the nest for earth, but remained on the top of the heap close to the edge of the precipice. Its business was altogether different from the others. For as fast as the eight put their loads on the heap, this particular ant picked up each load and pitched it over the brink of the precipice. Thus it was clear that the making of the heap was the duty of this particular ant.

Other illustrations of this relay system have been met with in the American Tropics. Bates describes the excavations of *Eciton legionis*.[1] One set of excavators carried up earth; their comrades, "with an appearance of forethought that quite staggered him," relieved them of their burdens, and carried them a sufficient distance from the hole to prevent them falling back again.

Belt forced a nest of *Œcodoma* to migrate.[2] The ants, however, during the migration, did not carry their burdens in the usual way. There happened to be a slope on their line of march. See the effect it had on the ants. They divided themselves into two parties. One party took the loads to the top of the slope, and from there rolled them down to the bottom. The other party kept at the foot of the slope, picked up the fallen loads and carried them to the new nest.

Now, can we explain these co-ordinated actions in terms of instinctive impulse? I cannot believe it. I need not discuss Belt's example. The intelligence employed is so glaringly obvious. But take the nine ants making

[1] *Naturalist on the River Amazon*, p. 357.
[2] *Naturalist in Nicaragua*, p. 61.

the heap. Eight were diggers: one was a heap-maker. The plan of work was quite unusual. As a rule all the excavators both carry out earth and construct the heap. But then, in this case, their heap was unusual. It was flat on top and precipitous in front, the unusual shape being due to the fact that the nest was situated on a slope. It was in order to meet the unusual situation that the ants had changed their ordinary method, and had assigned to one particular ant the shaping and general construction of the heap.

In the Himalaya I came across a better example. *Myrmecocystus setipes* is a powerful ant which was active at a height of 4,000 feet.[1] It had made a nest on the side of a bank. The ejected earth ran down from it in a shoot, like a landslip on the face of a hill. The shoot was very steep and crumbling, and as each ant carried out its load, it slipped on the loose material and tumbled down to the bottom of the slope. The ants, however, refused to be defeated. After some days of slipping and falling they managed to devise an ingenious plan of getting over this serious difficulty. They assigned to one particular ant the duty of consolidating and hardening the ground. This ant set about collecting pebbles which it found near the foot of the shoot. These pebbles it carried up the shoot and spread them out in the form of a platform at the very top of the shoot, that is just outside the mouth of the nest.

This was tremendous labour for one ant. The carrying of the pebbles up the slippery shoot was a task that lasted several days. It required all the labourer's strength, and caused it innumerable falls. It was interesting to see selection at work. The ant never took the

[1] *A Naturalist in Himalaya*, p. 55.

first pebble that offered. Several were examined, picked up and tested, until one was met with that fitted the job. Moreover it did not place its pebbles haphazard; it carefully found a suitable spot for the fitting of each load. The final result was a platform of pebbles on which the excavators walked easily, and no more of them fell down the slope.

Can we deny intelligence to this? Is this the action of an automaton, a thing that works blindly like a machine? Is this the mere reflex activity of Bethe or the plant-like behaviour of Loeb? Of course it isn't. Intelligence runs all through the act. There is *divergence* from accustomed habits; there is *choice* in the selection of pebbles; there is *design* in the making of the platform; there is the final *end in view*, and one very much to the advantage of the ants.

I can no more deny intelligence to this act than I can to a man who builds a parapet to prevent people tumbling down a hill.

It is important for excavating ants that the excavated earth should not fall back on them. For this reason they either carry it away a little distance or pile it up in some suitable shape. These, of course, are instinctive activities. The earth is disposed of on a racial plan. The ants continue the instinctive method which their ancestors employed before them. But sometimes we meet with intelligent adaptations. I suspect this of *Myrmecocystus setipes*. I once saw it putting pebbles round its nest which looked as if a wall was being built to prevent earth from tumbling in. What confirms me in this is an observation by Donisthorpe.[1] He found a nest of *Donisthorpea nigra* situated in the sand dunes at Tenby.

[1] *British Ants*, p. 203.

The colony had made an unusual adaptation, one specially suited to its sandy surroundings. It had built a sand-crater at the entrance to its nest, without doubt in order to prevent loose sand from being blown into the nest by the wind. Again we have an unusual deviation with a highly advantageous end in view. The deviation cannot be instinctive. It is not these ants' instinct to make craters. In the sandy tract they did it designedly, in order to secure a distinct gain. It was not instinct but reason that built it. Yet that is exactly, according to Fabre, what the ant is unable to do. "We can get them to give us an enormous cone of earth, an instinctive piece of work, but we shall never obtain the juxtaposition of three grains of sand, a reasoned bit of work." I maintain that the crater built at Tenby is a reasoned work of juxtaposition.

Their Intelligence as Nest-Makers

The remarkable activities of the Red Tropical Tree-Ant supply the best illustration of this. I have carefully observed their behaviour in India, and I feel confident that anyone seeing it will admit that the ants understand what they do.

The ant in question is *Œcophylla smaragdina*. It makes a large conspicuous nest in the mango and other trees. What concerns us here is the making of this nest, the way by which the ants draw the leaves together and fasten their edges with silk.

First, how are the leaves brought together? It is done in the most ingenious way. The ants stretch across from leaf to leaf. The edge of one leaf they grip with their jaws, the edge of the other with their hind legs. Then they pull, and the leaves come together. If the leaves happen to be so far apart that single ants cannot

span the gap, then they make themselves into chains. Two workers link themselves together. One grips the other by the waist, and in this way they almost double their length. If the gap is still wider, then three or even

Fig. 16.—Red Ants drawing leaves together.

four may join in the chain. Should the gap happen to be of varying width, then the ants will so adjust their linkings that single ones pull where the gap is narrow and linked individuals where it is wide.

The pulling is done with remarkable precision. The ants range themselves side by side like so many dis-

ciplined men. They do not haul irregularly; they never pull against one another; there is nothing wasteful or intermittent in their efforts. All their jaws grip one edge; all their hind legs grip the opposite edge. The act is the very essence of team-work. It reminds one of a line of sailors all lying side by side out along the yard of a ship. As the leaves come together, the ants adjust themselves, taking purchases with their legs farther and farther back until the gap is completely closed.

Fig. 17.—Red Ant using its larva to stitch leaves together.

Their second operation is even more wonderful. The leaves have come together. They must now be fastened with silk. Ants of themselves cannot make silk. They must get it from some other source. In this case they take it from their own larvæ. As soon as the leaves have been drawn together an ant appears with a larva in its jaws. It lifts the larva from side to side, and gently applies the larva's head to the edges of the approximated leaves. The movements of the ant are very rhythmical. It looks rather like a swinging pendulum as it carries the

larva from edge to edge. Now, wherever the larva touches a leaf it attaches a thread of silk. This silk it possesses for cocoon-making purposes, but in this case the ants make their larvæ employ it for stitching the leaves of their nest. Moreover the larva co-operates with the ant. It never neglects to affix a thread, also it bends its head to the leaf each time it is lowered by the ant. This continues for hours and days. When one larva is exhausted another is brought. Millions of threads are spread from side to side. In the end the leaves are firmly fastened by a strong white layer of silk.

Now for a modification of the usual act. I occasionally

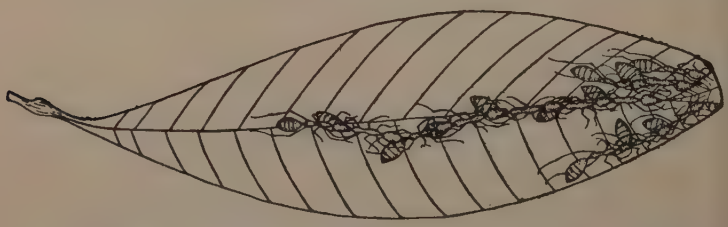

Fig. 18.—Red Ants bending a single leaf.

met with very small nests made out of one long leaf bent completely over on itself. The top had been brought down to the base and the edges all round fastened with silk. The question arises: How was it done? Here there are no gaps to stretch across. It could not have been done by throwing chains across spaces. There is only one leaf concerned. How did the ants double it on itself?

By a fortunate chance I was able to find out. One ant first gripped the tip of the leaf. A second ant took the first ant's waist, a third fastened itself to the second, a fourth to the third, and so on until a chain was formed down along the midrib of the leaf. Then they all pulled

together. The tip began to bend. As it bent, the pullers retreated, taking purchases farther and farther back. Other individuals now came forward, and gripped the turned-down end of the leaf on either side of the extreme tip. Some pulled as individuals; others made chains. The bending advanced, and as more of the leaf came down more and more ants were able to join in. Though the leaf was tough, yet the work was done quickly. In fifteen minutes they had brought the tip down to the extreme base of the leaf. Then followed the second operation. Larvæ were brought, silk emitted, and the margin of the leaf fastened all round.

Now, I cannot believe that all these adjustments can be explained by blind instinct. The ants have to accommodate their actions to a crowd of ever-changing incidents that differ in every nest. For example, there are those mutual adjustments, the adjustments of the ants one to another, whether they pull as isolated individuals, whether they join together in pairs, whether they link themselves into chains. And these adjustments keep changing ceaselessly from the beginning to the end of the task. Then there are adjustments with respect to the leaves, as to whether the spaces are narrow or wide, whether the leaves are long or round, whether the nest is one-leafed or many-leafed, and so on in a host of particulars. And as every nest differs from every other nest these adjustments have no end. We see, therefore, a ceaseless adaptation to an endless variety of changing conditions. Is behaviour that possesses that ceaseless adaptation explicable in terms of blind instinct? The main act, of course, is one of instinct. It is the instinct of that species of ant to make that wonderful type of nest. But, in addition, there is something else. There is something that controls these innumerable adjustments, something that adds light to the blindness of the instinct.

That something, I believe, is the ray of judgment that runs through the whole act.

There is another Indian species, *Polyrhachis simplex*, which employs the same silk-producing mechanism, but instead of uniting large leaves, it stitches together bits of débris and grass.[1] The nest is often about as large as one's fist, and in the wall are one or more doorways just large enough to allow the entrance of the ants. I once put a bit of camphor in a nest, the door of which happened to be so narrow that the ants could not get the offensive stuff out. Of course the camphor caused the greatest agitation. The ants for some time kept blindly pulling at it, and trying to force it through the narrow door. At length, however, they gave up doing this, and turned to what was clearly intelligent. They set about enlarging their door. Some dragged away the fragments of grass; others pushed back the silken wall. In the end they widened the door sufficiently for those inside to push the camphor out.

Ants have been kept in artificial nests, and their behaviour under such conditions sometimes clearly indicates intelligence. One of the best examples that I know of is an observation made by Miss Fielde. The ant in question was *Aphœnogaster picea*.[2] Miss Fielde placed a crowd of them on a heap of earth surrounded by a watery moat. The earth was dry and the ants disliked it. For some reason this species is reluctant to dig unless the soil is moist. However, they were able to find a remedy. During the night they went to the

[1] *A Naturalist in Hindustan*, p. 113.
[2] Quoted in *Ants*, by Wheeler, p. 195.

moat, carried water to the dry earth, moistened as much of it as would fill a pint pot, and, in this now suitable environment, built themselves an acceptable nest.

Now these two last examples we may group together. The clearest intelligence underlies both. One lot of ants wants to get the camphor out; the other lot wants to get moisture in. In each case they are up against a novel experience; in each case they deal with the problem intelligently, and in doing so depart altogether from the accustomed duties of their lives. How hopeless is it to say with Fabre that "our logic is not the logic of the insect." If there is any meaning in these acts, it is that the methods employed by the ants are the same as would have been employed by ourselves.

Their Intelligence as Roadmakers

I have often seen ants making roads, permanent pathways that lead to the nest. This is done by *Holcomyrmex scabriceps*, a harvesting ant common in India. The ants in their explorations make a discovery. They find a patch of grass or other vegetation that bears nutritious seeds. The ants set about collecting these seeds. First they plot out a rough track between the seed-producing area and the nest. Then some of them start making the track into a road. They drag aside pebbles and bits of débris, cut down inconvenient stalks of grass and throw them on one side of the road. In the end they make a smooth and well-defined thoroughfare along which they move backwards and forwards carrying seeds into the nest.

Such work surely demands intelligence. Consider the host of little problems involved, the innumerable adjustments to varying circumstances that must be involved in making a road. Imagine a crowd of human beings

doing it. Grant them the most complicated instincts imaginable, nevertheless it will not suffice. A thoroughfare could never be constructed by blind instinctive impulse.

When obstructions occur on an ants' pathway they often manage to surmount the difficulty by means which we must consider intelligent. There is a good instance from Central America recorded by Dr. Ellendorf.[1] He refers to the leaf-cutters, *Œcodoma cephalotes*, which carry leaves along well-marked roads. One day he pressed a thick branch into the earth across the ants' road. The ants first tried to climb over the obstacle, but failed owing to the weight of their loads. Then they proceeded to tunnel underneath it. First they laid down their loads, then commenced to dig a tunnel, working from opposite sides of the branch. The tunnel was finished in half an hour. Then they again took up their loads and carried them under the branch.

The nearest thing to this that I have observed was during a migration of *Acantholepis frauenfeldi*. This is a small Indian ant which migrates in immense swarms. Each ant carries with it a larva as it moves from the old to the new nest. One day I blocked with small stones the opening of the nest to which the ants were migrating. This produced tremendous agitation. The ants, however, behaved very rationally. They began by finding a safe place for their larvæ, a hollow beneath the shelter of some grass. Then they deposited their larvæ in this hollow, after that went to the nest and pulled out the obstructing pebbles, then went back to the hollow, picked up their larvæ and carried them into the nest.

[1] Quoted in *Animal Intelligence*, by Romanes, p. 96.

A more striking illustration is given by Belt.[1] He met with a column of leaf-cutting ants which, in order to reach the leaf-bearing trees, had to cross the rails of a tramway. Wagons were continually running on these rails, and numbers of the ants got crushed to death. What did they do? They gave up the dangerous crossing, and made a tunnel under each rail. Belt then stopped these tunnels with stones. The ants in reply made a fresh pair of tunnels. Surely these ants knew what they were about. Belt's view, I believe the correct one, was that "a general understanding had been come to that the rails were not to be crossed."

If a road is made impassable by some sticky material, ants will often cover this material with earth and in this way reopen the road. Wheeler will not grant that this act is intelligent, because ants instinctively do this on any sticky substance close to their nest. But, with great respect to Professor Wheeler's authority, I think he rather misses the point. If the object of the ants is just to cover the material, if the scattering of bits of earth just results in their concealing something unpleasant, then the act may be regarded as instinctive, though one of a somewhat advanced kind. But instances can be recorded where the ants do rather more than this. They spread out their bits of earth with definite intention, and in order to fulfil some particular end.

For instance, Mr. Lander at Porto Santo saw a number of tiny brown ants coming through the window into his dining-room.[2] He tried to stop the invasion by spreading a sheet of fly-paper across the window-sill. The ants, however, refused to be kept back. They built tracks

[1] *Naturalist in Nicaragua*, pp. 66, 67.

[2] *The Great Little Insect*, by Miss Cheesman, p. 245.

across the fly-paper with sand and bits of wood, and by means of these pathways continued to come in. Here we have an act which involves intelligence. It cannot be just a concealing instinct, for the sand and wood have not been scattered anyhow. They have not been pitched indiscriminately on the sticky stuff as they would have been were the act just some natural instinct to conceal. There is both design and motive in the operation. The material is laid out in a definite pathway to fulfil the end which the ants have in view.

Their Intelligence as Hunters

I can give no better instance of co-operation in hunting than the method adopted by the Indian Red Tree-Ant, *Œcophylla smaragdina*.[1] The act is very wonderful and I have watched it carefully. Nothing will convince me that blind impulse can guide all the innumerable adjustments required for the performance of this remarkable feat.

To begin with, let us see what happens. A Red Ant is searching for prey. It finds, let us say, a large longicorn beetle, grips it by the leg and tries to hold it down. Other ants near by see the struggle and enclose the capture in a ring. Now follows the extraordinary procedure. The ants proceed to stretch their victim, to lynch it until it is dead. They spread themselves round it, seize it by every projecting point, legs, antennæ, edges of the wings. They all lie with their bodies fully extended and radiate outwards in all directions. Then the lynchers begin to strain, and to haul on the victim with all their strength. The beetle is helpless. It can do nothing in this terrible machinery but lie still and allow itself to be stretched. The number employed in this stretching process varies

[1] *Journ. Bombay Nat. Hist. Soc.*, Dec., 1923, p. 683.

with the size of the victim to be stretched. Half a dozen will stretch a small weevil; twenty will operate on a ladybird beetle; I have seen many hundreds engaged at stretching a young bird. The result of the stretching is to kill the victim It may be completed in four or five minutes, but a large capture will take half an hour. The ants, moreover, stick to it relentlessly. Whether the time be long or short, the ants persist till the victim is dead.

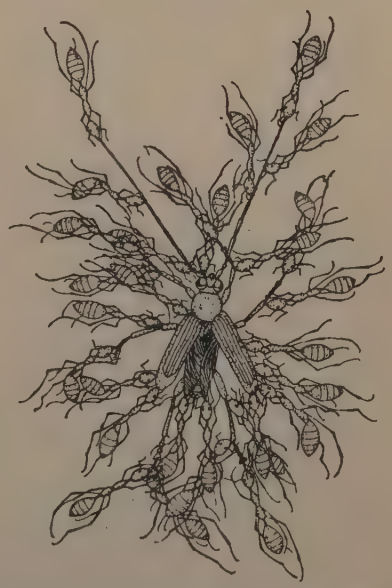

Fig. 19.—Red Ants stretching their capture.

Having lynched the victim, they proceed to remove it. It must be carried up to the nest. Most of the lynchers now retire. Sufficient remain for the duties of transportation, often a long and difficult task. In this act they show an admirable discretion. The position of affairs is this. A large burden has to be pulled up the tree-trunk, then out along the branches to the nest. See how the ants apply themselves to the task. Most of them get above the burden, grip it by every available point and haul it up the tree. Just two or three attach themselves below, and these keep the burden steady while the ones above persistently haul. Should a check occur on account of some obstruction, then other ants join the gang of porters until the burden is again on the move. In the

end they get it up the trunk and out along the branches to the nest.

Again I ask the same question : Can all this complicated and co-ordinated behaviour be attributed to blind instinct ? These ants are the ones that hauled the leaves together, and we showed then the inability of instinct to explain their innumerable co-ordinated acts. Surely it is the same in this operation. What adjustment must there not be in the stretching machinery, in the mutual adaptation of one ant to the other, in their numbers to the size of the creature to be stretched, in their time to the period required to kill it ? What adjustment must there not be in the act of transportation, in the numbers required to carry the burden, in the way they arrange themselves to hoist it upward, in the skill with which others lend assistance should a stoppage occur on the road ? Again I say, instinct will not explain it. Nor is it enough to speak of discernment. Such a complicated, co-ordinated and changing process demands a gleam of consciousness in addition to the instinctive act.

Fig. 20.—Red Ants transporting their capture.

I pass to another quite different ant. *Pheidole indica* is common in India. It nests on the ground, often under

stones. The chief thing about it is its two castes of workers. One caste consists of tiny individuals; the other is composed of a few large soldiers with immense square heads.

I saw these ants discover a beetle which was hiding in a crevice on the ground. They started to try and drag it out, while the beetle struggled to remain inside. A number of soldiers got hold of its antennæ, hauled stubbornly on the two ropes, but the beetle refused to budge. This went on for eight or ten minutes. Still the beetle held its own. Then I observed a change in tactics. The soldiers gave up their useless pulling, but they kept a firm grip on the beetle in order to prevent it going deeper into the cleft. The smaller caste of workers now joined in. They began to dig the beetle out. While the soldiers held it, the smaller ones unearthed it. They tore down the sides of the crevice, broke up the earth all round the beetle until in the end they got it out. The incident is instructive in two ways. We see the special value of two sets of workers, and we get an illustration of intelligent behaviour. For here we have ants involved in a predicament, and adapting their resources to that predicament in a highly rational way.

The British Wood Ant, *Formica rufa*, has been seen to employ the same kind of tactics. Miss Cheesman had them housed in the Zoological Gardens.[1] One day she gave them the larva of a tiger beetle. It was placed in a hole on a bank close to one of the ant colonies. In a few minutes a soldier found it and tried to pull it out of the hole. But this larva possesses a hook with which it grips the soil. As a consequence even five ants together were unable to haul it out. They kept trying to do so for almost an hour. Then followed the change in tactics. Two of them went to the back of the burrow, dug themselves in behind the larva, and by biting at its body, forced it out.

[1] *Everyday Doings of Insects*, p. 147.

A delightful example of ant-intelligence came under the observation of Mr. Swynnerton in Rhodesia.[1] He gave the caterpillar of an Acræid butterfly to an army of *Dorylus* ants. Now these caterpillars are armed with bristles from which they exude drops of liquid, a substance highly disagreeable to ants. The ants wanted to carry off the caterpillar, but they would not face the disagreeable liquid. What then did they do? They did an almost incredible thing. They began by collecting crumbs of earth and placing these crumbs on the ends of the bristles. The crumbs of earth, being very dry, soaked up the disagreeable liquid. Then the ants bit off the bristles. Fresh drops appeared where the bristles were severed. The ants then applied a fresh lot of crumbs, then cut the bristles a second time still lower down. And this was continued until many of the bristles were razed level with the caterpillar's skin. In this way the liquid-squirting mechanism was destroyed. Then the ants gathered freely round the caterpillar, killed it and carried it off.

If such behaviour is not intelligent, then words fail me with which to describe it. Fabre asks the plain question, "What happens in that little Hymenopteron brain? Has it faculties akin to ours, has it the power of thought?" His answer is a direct negative. "If anyone sees a rudiment of reason in this Hymenopteron intelligence, he has eyes that are more penetrating than mine. I see nothing in it but an invincible persistence to the act once begun."

Fabre's answer is perfectly clear. The Hymenopteron brain is devoid of reason. Put the same question to these *Dorylus* ants, and they answer in a different strain.

[1] *Trans. Ent. Soc. Lond.*, 1915, p. 345.

Their Intelligence as Ravagers

I come now to a different class of operation, also connected with the capture of prey. The Foraging Ants of South America have been said to hunt on a remarkable system. Armies have been seen entering houses, ascending in regular files to the rafters, chasing and capturing cockroaches in the roof, pitching the victims down to their comrades who carried them off with remarkable rapidity.

I might have been a little sceptical of this, had I not met with something analogous in the Plains of Central India.

The ant in question is *Lobopelta*. It is in the habit of despatching armies with the object of plundering termites' nests. I saw one of these armies at their ravaging operations. They had arranged themselves in a double stream. One stream was advancing to battle. The other stream was burdened with victims which they had pillaged from a termites' nest. At the nest itself a great struggle was in progress. The ants had broken into the termites' galleries ; the termites were putting up a fierce fight. Now the ants, in their attack, behaved very judiciously. They divided themselves into two parties. One party made themselves fighters. These entered the termites' galleries, slew the occupants, and dragged their dead bodies outside. The other party made themselves porters. They took up the bodies thrown out by the fighters and carried them back to their own nest. It was wonderful to see the precision of this action. A fighter would appear with a termite in its jaws. It would push its victim through the broken gallery. A porter outside would immediately take it. The fighter would go back for more. How far more efficient is this behaviour than if the whole army had made themselves fighters. Had they done so, they would certainly have blocked the galleries and would probably have failed to evacuate the spoil.

Just one more example from the ravagers. *Formica sanguinea* is a slave-making ant which raids the nests of *Formica fusca*. Now, it would appear that the raided ant understands the nature and danger of attack. If we can show that this is the case then we must admit something more than instinct. McCook demonstrates the point to satisfaction.[1] He observed that the ants made their nests differently in accordance with whether they were safe from the enemy or exposed to his destructive raids. If the nests were situated in safe localities, then the ants raised them into a moundlet and scattered the gates over the heap without making any attempt to conceal them. On the other hand, if the nests were in dangerous places, then the ants either made no mound at all or at best made only a small one ; they scattered the débris instead of piling it ; they made few gates and carefully concealed them ; they spread rubbish about the nest with the object of either concealing the locality or making approach to the place more difficult.

These acts are all designed for protection. They cannot be explained on racial instinct, for they are done only on special occasions, namely, when the nest is open to attack. How is it that the ants are able to discriminate ? Why do they protect where protection is needed, and neglect it where it is not required ? I can see only one explanation. Because they know what they are doing. They do not act as mechanical creatures. They know the meaning of cause and effect. The conclusion, to my mind, is unavoidable. Because they understand the dangers that confront them, therefore they take measures to defend their home.

[1] *Proc. Acad. Nat. Science*, Philadelphia, 1887, p. 29.

CHAPTER XII

INTELLIGENCE IN ANTS (*cont.*)

Many ants, as is well known, sip up the fluid excreted by other insects. Moreover, they guard and even stable these insects; they stroke them in order to get out the fluid; in fact, these insects are often regarded in the light of cattle tended by the ants.

I have met with some interesting examples of intelligence in connection with this extraordinary act.

Their Intelligence as Cattle-Tenders

It is well known that ants stand guard over their cattle, also that they build for them special stables, also that they carry them from place to place. But, in addition, I have seen them driving their cattle, and doing so with almost as much judgment and precision as any herdsman might adopt.

Here are the details of this wonderful behaviour. If the reader will not regard it as intelligent, then he had better close this volume.

Polyrhachis simplex is a cattle-tending species very common in Central India. As a rule it tends Membracids, small triangular, spiny insects, which shoot out drops of fluid whenever they are stroked by the ants. The ants protect them with great attention; the Membracids in return supply their protectors with the so-called milk. In addition the ants build sheds for their cattle, usually

either oval or tunnel-shaped chambers made of bits of grass interwoven with silk. These cattle-chambers have circular entrances, large enough to permit the entrance of the ants, but too small to allow the cattle to escape.

I have sometimes watched a single ant, but more frequently a pair of ants, driving one of these Membracids up a stem towards its shed.[1] It was wonderful to see how they coaxed it on, urging it from behind with the tips of their antennæ, using persuasion rather than force. If it tried to turn back, they pushed it onward; if it went off along a side stem, one of the pair ran out beyond it and drove it back to the correct road. Thus the ants kept it to the strict route and persistently urged it up to the nest.

One day I found a shed that had been damaged by a storm. The wind had torn a large hole in it, and the cattle were escaping down the tree. I watched to see what would take place. Four ants went after the straya-ways, got below them and cut them off. They probed them with their antennæ, bit at them with their jaws, by applying force compelled them to turn, then drove them with gentle prods of their antennæ back to the damaged shed. They got them in, guarded the opening, and later in the day repaired the hole.

Surely these facts, in all their implications, display an astonishing amount of intelligence. I recommend them to the advocates of blind automatism, and to those who would grant a niggardly discernment. "Our logic is not the logic of the insect." Then what, I ask, is the logic of the ants? Their behaviour in a special emergency is the behaviour of human herdsmen. All the Fabres and Bethes that ever lived could not make me deny what this incident teaches; that the ants well knew what they were doing and the reason why they did it.

[1] *A Naturalist in Himalaya*, p. 111.

The caterpillars of certain Lycænid butterflies are frequently attended by ants in India. The ants protect the caterpillars, and the caterpillars squirt out fluid to the ants. Now the ants drive about their caterpillars in the same way as they do the Membracids. In India I have seen the Large Black Ants forcing a caterpillar to their nest at the foot of a big tree. Getting behind it, they prodded it forward, never attacking it, but just

Fig. 21.—*Polyrhachis* ants driving cattle to their nest.

patiently persuading it, and sticking at the job hour after hour. The caterpillar had been feeding on the foliage. It obviously wished to turn back to its pasture. But the ants would not let it. They had their own particular intentions. They knew that the caterpillar was fully grown, and were determined to get it to the nest and to force it to pupate inside. Therefore they drove it very slowly but relentlessly. And not only did they drive it, but ferociously protected it. If I interfered,

they ringed themselves round it and rushed forward to defend their prize. In the end they fulfilled their object and got the caterpillar into their nest.

A spectacle of this kind is so remarkable that I shall add to my own observation the testimony of three other eminent witnesses.

Bell, the chief of Indian field-lepidopterists, says that the caterpillars of *Aphnœus hypargus* are always attended by ants.[1] These caterpillars, when they moult, build temporary shelters, and two or three of them join together for the purpose. But they do not come together on their own initiative. They are forced into this partnership by the agency of the ants, *who pilot them to the particular spot.*

L. de Niceville, whose authority is unquestionable, says that the caterpillars of *Taurcus theophrastus* are driven about by the Indian Black Ants.[2] The ants have their nest at the foot of a tree. They find a caterpillar in the foliage, *drive it downward* and force it to the nest.

Austin Clark goes even one better when dealing with a Ceylonese species.[3] He states that the caterpillars of *Aphnœus lohita* are attended by *Cremastogaster* ants. The ants keep guard over their caterpillars and build special shelters in which to house them. But here comes the almost incredible occurrence. The ants literally graze their caterpillars. Each night they drive them out to feed, and in the morning drive them back to their sheds.

The protection which ants give to their caterpillars is as strict as they give to their own larvæ. Thomann noted this in Switzerland, and records that, when he brought his finger to the caterpillar, the ants opened

[1] *Journ. Bombay Nat. Hist. Soc.*, Vol. XXVI, p. 484.
[2] *Ibid.*, Vol. III, p. 167.
[3] *Report of the Smithsonian Institute*, 1925, p. 442.

their jaws and attacked him. Ants will help their caterpillars in difficult situations ; for example, will pull them back on a stem when they are in danger of falling off. Later, when the caterpillar becomes a chrysalis, the ants will actually help the caterpillar to free itself from the chrysalis-case.

But by far the best instance of this kind of protection is one recorded from North America.[1] The ants have there been seen driving off parasites that were trying to lay eggs in the caterpillar's body. This is vouched for by Karl Coolidge. The caterpillar is the larva of *Brephidium exilis*, one of the smallest butterflies in the world, and abundant in Southern California. Its particular enemy is a Tachinid fly. Now the ants not only tend the caterpillar, but also drive off the dangerous fly. This is what happens. The caterpillar is on a leaf ; the ants are around it. The fly alights on the leaf and tries to get its egg into the caterpillar. Immediately the ants become greatly excited. They rush about over the caterpillar's body. By their frenzy and scamperings they alarm the fly. It makes a few fruitless efforts to lay, then gives it up as a bad job. The impression made on the observer was that the ants were "aware of the danger to their larva, and were certainly responsible for its being saved."

These various observations with respect to cattle are not explicable in terms of instinct. The behaviour is not routine behaviour. The ants have adopted rational devices to meet particular ends.

Their Intelligence in Mutual Relationships

That ants lend one another general assistance can be easily shown by innumerable observations. We have

[1] *Entomological News*, Vol. XXXV, p. 116.

several examples in those that I have given. For instance, when four ants drive a caterpillar, each must assist and co-operate with the other. Or when they extract a beetle from a crevice, one lot pulling and the other lot digging, it is difficult not to picture mutual aid. Better still that example of *Camponotus compressus*, where one ant built the platform of pebbles to prevent its comrades falling down the shoot.

I have said that such behaviour necessitates intelligence. But here I am concerned with the belief that one ant feels the wish to help another.

I shall quote a few facts bearing on this.

It is an old experiment to half bury an ant where its companions will easily find it. The ants have frequently been seen to liberate it by dragging it out of the earth. Belt placed a stone on an Eciton ant.[1] Its comrades came to it. Some pulled at the captive; others at the stone, and by mutual co-operation they got it out. Another he confined beneath a piece of clay. One ant found it and tried to extract it. Failing to do so, it went off for help, brought a dozen companions, who started to dig and soon set the prisoner free. I have tried the experiment with *Myrmecocystus setipes*. The ants showed the same appreciation of the problem. They set about digging and unearthed their companion. But in their case the object was not to liberate it; they dragged it for food into the nest.

Ants will rescue their companions in other emergencies. Wheeler kept *Eciton schmitti* in captivity.[2] A watery moat surrounded its nest, and the ants repeatedly happened to fall into it. When this occurred, other ants reached down and pulled out their drowning comrades.

Into a nest of *Messor barbarus* I once poured a pint of

[1] *Naturalist in Nicaragua*, pp. 23, 24.
[2] *Ants*, by Wheeler, p. 537.

water. The act caused a good deal of consternation. The ants abandoned their harvesting business and forced their way into the flooded nest. After a while some of them came out carrying in their jaws the half-drowned inmates. These they transferred a few inches from the nest, laid them carefully on the ground where they dried and recovered in the sun.

These actions suggest feelings of affection. But, even if that will not be admitted, at any rate they require intelligence.

Ants sometimes arrange themselves in rings to protect their companions under special circumstances. I have met with some wonderful examples amongst Termites, but never with the true ants. Moggridge, however, observed it with *Atta barbara*.[1] The ants were trying to protect their queens which lizards at the same time were trying to destroy. Their plan consisted of a ring around the queens, a barrier which the lizards were afraid to break through. Miss Cheesman, in the Society Islands, saw something similar with *Tetramorium simillimum*.[2] She threw food to the ants. Their soldiers came out, made a ring around it, kept back all other competitors while the smaller workers took it piecemeal away.

We have seen that ants will help one another. There is also another side to the picture. For ants will sometimes coerce one another. The best illustration I have seen of this is the way in which workers will coerce their queens. I have seen it take place amongst different species, but I specially refer to *Camponotus compressus*. Before sunset the queens are accustomed to come out,

[1] *Harvesting Ants and Trapdoor Spiders*, p. 163.
[2] *Islands near the Sun*, p. 145.

wander about near the nest, and seem unable to find their way back. Though sometimes unable to get home themselves, yet they are not allowed to be out after dark. The workers go after them, seize them by the necks, hoist them in the air and march them to the nest. Ants in the same way, at migration periods, will sometimes deport their queens. If the queen lags behind or does not join in the migration, a worker will grip her, lift her in the air and deport her bodily to the new nest.

A certain little fact has often struck me with respect to the mutual relationship of ants. This is the way they adjust their numbers to the magnitude of the task in hand. I particularly noted it with *Cremastogaster auberti*, an ant which frequents fig-trees at Baghdad. Give a bit of food to one of these ants. The ant will go off to the nest immediately and despatch a party to retrieve the spoil. The party will find it without much trouble, gather around it, pull it to pieces, and carry off the fragments to its nest.

But the point is that the number of the ants despatched is proportionate to the size of the spoil. The ants do not pour to the place indiscriminately. There seems to be some gleam of judgment in the act. An experiment will show what I mean. I cut a grasshopper into three bits. The first bit is one-fifth of an inch long. The second bit is twice the bulk of the first. The third bit is twice the bulk of the second. I give the three bits to three separate ants at different places on the same tree. All three ants hasten to the nest. Each sends a party to its own bit. I leave them alone for forty minutes and then count the number of ants which have been despatched to the separate bits. There are twenty-eight at the smallest fragment, forty-four at the intermediate one, and

eighty-nine at the largest piece. These numbers are roughly double of one another, that is they stand in the same proportion as do the bulk of the bits.

I think such behaviour demands some judgment. It is inexplicable on blind routine.

Their Intelligence as Bridge-Makers

The way in which ants make bridges and ladders strikes me as an excellent display of intelligence. I have witnessed the act on several occasions, for that ant which made chains to pull leaves together, the Indian Red Tree-Ant, *Œcophylla smaragdina*, is a bridge-maker of the best type.

Their bridge-making powers are very instructive. Here is one of the prettiest examples I met with. A stream of ants was climbing through the foliage. At one place their progress was obstructed. There were wide gaps between the leaves, and the ants were unable to get across. They overcame the difficulty by making a bridge. One ant had undertaken this duty. With its jaws it had gripped the edge of one leaf; with its hind legs the edge of the opposite leaf. It had managed to pull the leaves close together, and, though clearly put to a great strain, it was keeping them from flying apart. Every minute hundreds of ants crossed over this simple solitary bridge. They were all dependent on this one ant. If it broke its hold, confusion would result, and thousands of ants would be isolated from the nest.

I watched this bridge-maker for half an hour. During that time it never moved, while thousands crossed it from leaf to leaf. I then cut the bridge. Consternation followed. Crowds of ants assembled on either side and for a time could not get across. But soon another ant came to the rescue, made itself into a new bridge, and very soon order was restored.

This is the best example of individual co-operation that I have yet met with in ant life. Here we observe a

Fig. 22.—Red Ants making a bridge.

solitary worker giving itself up to the common weal. It cannot be merely instinctive behaviour. The act repre-

sents a special adjustment to meet a particular end. The ants must understand the problem that confronts them and decide on the way in which it should be solved. This is what Fabre says the insect cannot do. "It has no choice as to what it shall do; it cannot discriminate between what is and what is not advisable; it glides, as it were, down an irresistible slope prepared beforehand to bring it to a definite end."

It is a strange kind of gliding down an irresistible slope when ants come up against this special emergency and solve it by this remarkable bridge.

This building of bridges is so impressive that I shall give a few more illustrations. Belt, in Nicaragua, saw a column of Ecitons trying to make their way across a watercourse.[1] They were using for this purpose a slender branch which was no thicker than a goose-quill. But, finding this natural bridge too narrow, the ants had widened it with their own bodies. They had linked themselves together on either side of it, increasing its width three times. The result, of course, was a great advantage. The ants could now cross three or four abreast. Otherwise they would have had to go in single file, and the crossing would have taken them three times as long.

"Can it not be contended," Belt remarks, "that such insects are able to determine by reasoning powers which is the best way of doing a thing, and that their actions are guided by thought and reflection." I feel sure that anyone, seeing these bridges, will agree with Belt's conclusion.

Here is another remarkable illustration. Bar saw a column of *Eciton hamatum* crossing a column of *Atta cephalotes*.[2] The Ecitons refused to march through

[1] *Naturalist in Nicaragua*, pp. 24, 25.

[2] *Le Monde Social des Fourmis*, Vol. V, p. 23.

the *Attæ*. They had found a stick which stretched across, and were using this as an overhead bridge. Bar took away their bridge. Confusion followed. The Ecitons came to a halt and refused to go through the *Atta* column. A few centimetres away was another piece of stick. The Ecitons found it and began to use it as a second bridge. Unfortunately for them it was very narrow, no thicker than the handle of a pen. They tried it, but it did not suit. Then, see what they did. Ten, twenty, fifty individuals clung to either side of the stick. They made themselves into a double row, widened the bridge, and the column passed over. Bar again destroyed the bridge. More confusion! There were now no other sticks available. This bridging business must therefore end. The Ecitons will have to pierce the *Atta* column; otherwise their line will permanently break.

They attempt it. Tremendous disorder! Apparently at first they have not much success. At length, however, comes a great effort. Suddenly and simultaneously, as if by command, a multitude of Ecitons throw themselves on the ground, cling to the earth with their long legs, and arrange themselves in several rows over a distance of 20 to 30 centimetres. Others climb on top of them, make a second layer. Still others get on top of these and form a third layer. Simultaneously two of these walls are fashioned, 5 to 6 centimetres from one another. The rest of the Ecitons climb across them in triumph. The *Attæ* take flight in every direction.

I will not comment on this wonderful behaviour. The plain facts are eloquent enough.

Related to this power of manufacturing bridges is the capacity to make chains. I shall again give my own observations with respect to *Œcophylla smaragdina*.

I took a nest of these ants from a tree. The nest, as I have already said, is made of leaves united with silk. I stood it on an island in a basin of water. It had a long stem with plenty of foliage, and some of the leaves extended outward a few inches beyond the edge of the basin. The ants very soon became dissatisfied. They came out in multitudes from the nest, explored the leaves, ran up and down the stem, and tried in every way they could to escape from their unfortunate island. I imagined that I had them safely marooned since they could not possibly cross the water. But I found myself very mistaken. I had not appreciated their powers of resource. All went well for the first day. But on the second day they got particularly restless. I saw them exploring every point.

Now, at one place a leaf stretched beyond the basin and drooped to within two inches of the ground. At the tip of this leaf the ants began to concentrate. They had picked it out as the most dependent point. Also it was clear that they could see the ground beneath them. I thought at first they were going to let themselves drop. But soon I saw that they had a better method. One ant hung down to its full extent clinging to the leaf with its hind claws. A second then climbed down along its body. Then a third came down, then a fourth ; others followed ; and they all linked themselves together in a chain which ultimately reached the ground. The chain was fragile and would not bear much weight. But others soon joined in it, massed themselves round it, and made it into a thick rope. It must not be thought that these chain-making individuals were ants just trying to escape. On the contrary, they made the ladder for others. Those that made the ladder remained in the ladder. Though they could have easily got to the ground, they never tried to escape themselves. Those above, however, made

immediate use of them. Hundreds swarmed down this remarkable ladder, and I soon lost nearly half the nest.

FIG. 23.—Red Ants making a ladder.

Lord Avebury, in his delightful record of ants, expresses surprise at the inability of these insects to make a short drop through the air in order to reach some object beneath them. Thus, in one instance, they made a journey of nearly 7 feet rather than drop only half an inch. These tropical arboreal ants stand in an altogether different category. What would Lord Avebury have said of these chains? "In order to test their intelligence," he writes, "it has always seemed to me that there was no better way than to ascertain some object that they would clearly desire, and then to interpose some obstacle which a little ingenuity would enable them to overcome." Is not this construction of a living ladder sufficient to satisfy Lord Avebury's demands? The ants desire to escape from their island. In order to do so they must overcome an obstacle. They must either cross a foot of water, or descend 2 inches through the air. They choose the latter as the easier alternative; they suspend a ladder and escape.

The Driver Ants of Western Africa seem to be as clever at this ladder-making business as is the Tropical Red Ant

of India. Having seen *Œcophylla* escape from its island, I can easily credit *Anomma arcens* with throwing bridges across streams. Yet the act seems almost beyond credibility, though testified by different observers.

Here is what, we are told, takes place. The ants find a branch overhanging a stream. They get out to the end of it, make a chain, and hang down until the end of the chain reaches the water underneath. The chain then begins to float on the water. More ants come down and continue to lengthen it. It grows and grows and becomes so long that the current sweeps its end to the opposite bank. The ant at the end then clings to the bank, and the army crosses over by what must be the most curious bridge that has ever been constructed.

Another way in which this linking is exemplified is when ants collect themselves in swarms or balls.

The Driver Ants of Africa, at times of inundations, will mass themselves in a round ball. They collect their eggs and larvæ in the centre of it, and float in this ball-formation on the water till they reach dry ground or till the flood subsides. I have seen something of the same kind in India. The Large Black Ants, *Camponotus compressus*, nest on the ground at the foot of trees. When the monsoon breaks and the ground is flooded the ants often have to leave their nests. They usually find some hollow in a tree and remain in it till the flood subsides. But if trees are not available, then the ants are driven to extremities. In one place only bushes of tamarisk existed. The evicted ants got up into these bushes and collected themselves into globular balls composed of many hundreds of individuals. And there they clung in a motionless mass so long as the floods remained.

Something of the same kind has been met with even

amongst our British species. Mr. Donisthorpe saw a clustering of *Donisthorpea umbrata*.[1] He had these ants in an artificial nest. Around it was the usual trough which he filled so full of water that it overflowed into the nest. How did the ants face the inundation? They immediately clustered round their larvæ, enclosed them completely, and remained in this position under the water until it was absorbed by the walls of the nest.

We have now discussed a crowd of adaptations striking in the highest degree. There is linking and clinging, bridging and laddering, chain-making and ball-making, all of which imply extraordinary behaviour to meet special contingencies that arise. Can anyone believe that all this mutual co-operation is directed by some blind unconscious impulse? Such an idea is to my mind impossible. Ladders and bridges could never be made without some reflection and thought.

Learning by Experience

Can we prove that ants learn by experience? If so, then we prove that they possess something in addition to blind instinct. For what is instinct? It is something that the creature has inherited. What is learning by experience? It is something completely new, something which has happened for the first time in the lifetime of this particular individual. Instinct is, therefore, out of the question. For how could heredity have prepared beforehand for some particular innovation in the life of some particular individual?

If ants, then, can learn by experience, they must possess something in addition to instinct. What is that

[1] *British Ants*, p. 47.

something? In the first place it is memory. In the second place it is the power to make conscious adjustments. And if these adjustments are to its advantage, what else is it but intelligent behaviour?

Let us, therefore, prove our point. Ants kept in artificial nests certainly undergo a change in character. A striking illustration of this was brought to my notice by Mr. Donisthorpe. He showed me a colony of *Myrmecina graminicola* which he had kept in confinement for *seventeen* years. The ants had lost their natural timidity. But, more extraordinary, they were losing a habit of vital significance in their lives. The habit was that of rolling themselves into a ball whenever they happen to get alarmed. This rolling habit is, of course, protective. Their heads curl in and touch their tails, their antennæ and legs get pressed against their bodies, they lie still, shamming death, with only the hard integument exposed. After seventeen years of freedom from attack this protective habit had almost vanished. Some of them still made a feeble attempt at it; others would not curl under any stimulation. It was clear that this life-preserving instinct was on the point of being totally lost.

Miss Fielde divided into two parts an artificial nest of *Camponotus pennsylvanicus*.[1] The ants in one part she continually fondled until they felt quite secure in her presence. She succeeded in training them to climb up her fingers. They gave up their attempts to bite her, and remained quiet when she opened the nest. Those in the other part she intentionally maltreated both by plunging them into water and by pinching their legs. As a consequence of this they refused to get tame, and

[1] Quoted in *Le Monde Social des Fourmis*, Vol. IV, p. 27.

rushed across the nest in a panic every time she raised the glass. Here we have a clear example of learning checked by a definite control.

The following example of learning by experience comes from the Zoological Gardens of London.[1] A colony of Wood Ants, *Formica rufa*, was established in the Insect-House. The colony was surrounded by a trough of water which prevented the escape of the ants. Miss Cheesman fed her ants on mice. She always put the mouse on the same piece of ground, and the ants were in the habit of burying their mouse. Now, one day it happened that, while being buried, the mouse fell over into the trench. Confusion followed. Some of the ants tumbled in with it, and, of course, they lost their mouse. Another was given them, and was placed in exactly the same spot. Then came a change in the ants' behaviour. They adopted a different method of burial. Hitherto they had dug underneath the mouse. Now they dug on the inner side only, that is on the side away from the water. The reason for the change in method was to prevent the disaster recurring. For this new plan of burial forced the corpse to roll inward and away from the trench. Miss Cheesman remarks that it was not coincidence. Mice had frequently been given to the ants, and up till then they had always dug directly underneath. It was clearly a case of learning by experience. Indeed it suggests some mechanical knowledge, and certainly the possession of "intelligence not far removed from reasoning power."

So much for learning in artificial nests. Is there any evidence that ants can learn in the rough-and-tumble of their natural lives?

[1] *Everyday Doings of Insects*, p. 145.

Here is a very striking illustration. Mr. Donisthorpe met with an incident which shows that one ant can learn from another ant under the natural conditions of life.[1] *Donisthorpea fuliginosa* and *Donisthorpea mixta* are two species that occur in Britain. *Fuliginosa* is jet black, and has the habit of marching in files along a beaten track. *Mixta*, on the contrary, is dirty yellow, lives a subterranean life, seldom comes into the open, and never marches in files. But sometimes these two ants mix together and occupy a common nest. Mr. Donisthorpe saw this in the New Forest. See what happens when the two intermingle. *Mixta* takes on the habits of *fuliginosa*. It comes into the open, makes use of roads along which it marches in files.

That is a very extraordinary incident. One ant has learnt a habit peculiar to another species. The act has taken place under natural conditions. Something like it, though not so strikingly convincing, has been obtained by means of experiment. Forel took a bag full of *Formica pratensis* and emptied it near a nest of *Formica sanguinea*.[2] What happened ? War, of course, with the usual murder and pillage. It ended, however, in some kind of peace, for next year the nest was mixed. Both species occupied the same tunnels and worked together in perfect harmony. That fact is remarkable enough. The inveterate enemies of generations had become mutual allies.

But here comes a still more extraordinary fact. Forel now took a handful of ants from the original nest of *pratensis* and put them on to the mixed nest of *pratensis* and *sanguinea*. In other words, those *pratensis* ants which had become allies were receiving a handful of their old comrades taken from their original nest. Did they recognize them, or did they attack them ? Did they

[1] *The Entomologist's Record*, 1919, p. 4.
[2] *Le Monde Social des Fourmis*, Vol. IV, p. 10.

join forces with their foreign allies or with their old kith and kin? Without hesitation they joined their allies. They threw themselves ferociously on their old comrades, bit them, killed them, covered them with poison, in fact attacked them far more savagely than did the real owners of the nest.

I think that we must regard this remarkable change as in the nature of an education. To begin with hostility was changed to friendliness; then friendliness was changed to a strong alliance, so strong indeed that, when it came to a struggle, they fought for their allies rather than their kin.

This concludes my remarks on ant-intelligence. Do they indicate, as Fabre asserts, that the insect sticks to the path mapped out for it, that it "has no choice what it shall do."

Remember the ant that built the platform to prevent its comrades slipping down the shoot; remember the ants that raised a crater to stop the sand from being swept into their nest; remember the ant that became a bridge in order that its comrades might cross a gap; remember the host of similar incidents, not routine occurrences in the lives of these creatures, but special devices brought into operation in order to meet the emergencies that arise.

With these in mind, we emphatically disagree with the assertion that "the insect has no choice what it shall do." These creatures possess not only choice, but, in addition, no little judgment in the way that choice is used.

CHAPTER XIII

INTELLIGENCE IN HUNTING-WASPS

These are the exponents of surgical perfection which came into our chapter on the "Wisdom of Instinct." The reader will remember their amazing knowledge, how they behaved as if they understood the minute internal anatomy of their victims.

What does Fabre say of these wonderful anatomists? He says that "they know nothing about anything," that "they lack the smallest gleam of intelligence," that Nature has given them only "blind faculties, which cannot be modified by experience."

Let us see. We shall question these wasps at every stage in the rhythm of their fascinating instincts.

Their instincts vary according to the species. First they prepare a suitable burrow, then they go and capture a special type of victim, then they drag the victim to the burrow, then they lodge it inside the burrow, lay an egg on it and seal the door. Let us take in their natural sequence the successive steps in this instinctive chain.

Intelligence in Preparing the Burrow

The Peckhams tell us that *Pompilus quinquenotatus* makes two different types of nest,[1] according to the soil in which she has to dig. If the soil is a firm clay, then the wasp makes a straight tunnel with a slight enlargement

[1] *Wasps, Social and Solitary*, pp. 213, 214.

at the end. If the soil is loose sand, then the wasp makes her tunnel angulated. After going down half an inch, she bends her burrow at a right angle, and digs in an entirely new direction. This change in direction where the soil is loose must be regarded as an intelligent adaptation. The wasp accommodates means to ends. She bends her tunnel only at those times when the sand is liable to fill the excavation as fast as the excavator digs.

We cannot explain this kind of behaviour without granting the creature some glimmering of thought.

Intelligence in Capturing Prey

The instinct of capture is remarkably fixed. Yet now and then we meet with an occurrence which shows that the act is brightened with intelligence.

First let us look to *Sphex lobatus*, the huntress of crickets on the plains of India. This wasp drives the cricket from its burrow, then chases it over the ground. Its ordinary method is very simple. It digs down through the closed mouth of the burrow, gets behind the cricket and drives it out. But often the burrow has a second opening, a special avenue for the cricket's escape. This is a great disadvantage for the *Sphex*. When the wasp goes in one hole, then the cricket can slip out through the escape-opening, and easily elude its foe. Now the *Sphex* clearly understands this difficulty. For when this double avenue is present she adopts a very prudent method of preventing her victim slipping away. Instead of digging straight down through one gate, she keeps running to and fro from one gate to the other. She digs a little, then runs excitedly to the escape-opening, then runs back and digs a little more. In this way she watches both apertures, and will know immediately if her quarry slips out. I have often watched this clever strategy.

No one can do so without concluding that the wasp well knows what she is about.

Ferton, an observer of the strictest accuracy, gives another interesting example. The Wandering Pompilus, a French wasp, chases the spider, *Nemesia badia*.[1] The spider lives at the bottom of a shaft, which, like the cricket's burrow, opens at the surface by two holes. Both holes are provided with doors. The wasp begins by tearing off the doors. Then she tries to get the spider out. But she does not just rush straight down one opening. If she did so the spider would escape by the other. What she does is to stick her abdomen into one hole, then quickly pull it out and fix her eyes direct on the other hole. Her wings are kept raised and vibrating, ready to make an immediate rush should the spider happen to pop out. If this fails, then she goes to the other hole, repeats the same manœuvre there in the hope that the spider will come out through the first hole. In the end she manages to bolt the spider and gets it as it tries to escape.

Instinct, without some intelligent addition, to my mind completely fails when used to explain incidents like these.

Another, and quite different, type of strategy is that adopted by *Mellinus arvensis* in its efforts to capture flies. We owe the observation to Mr. F. Smith.[2] The ordinary method of this wasp is to walk about on patches of cow-dung. It moves about in an unconcerned way, and, when a chance happens to offer, it pounces on an unsuspecting fly. But at Bournemouth, where the flies were particularly active and the wasps could not get them by ordinary means, Mr. Smith witnessed a delightful

[1] Quoted in *Psychic Life of Insects*, by Bouvier, p. 179.
[2] *Cambridge Nat. Hist.*, Insects, Part II, p. 124.

variation. He noticed what he thought were dead specimens of this wasp lying about on patches of cow-dung. He tried to pick them up, but they flew away. He then realized that these wasps had a special ruse for capturing their flies. He saw their plan in active operation. A wasp lay on the dung, apparently dead. A bluebottle happened to approach and to wander within reach of the wasp. Then the *Mellinus* started into life, and made a pounce on the unsuspecting victim "as active as any puss." If the act was ordinary, then instinct would explain it; but here we have a particular ruse adopted to meet a special case.

The circumspection with which *Pompilids* battle with large spiders must imply an appreciation of danger. The one that I particularly call to mind is the Baghdad wasp, *Cryptocheilus rubellus*, fighting with the Black-bellied Tarantula. The tarantula is a huge and terrible enemy. It raises itself before the wasp, determined to put up a fight. The wasp shows the utmost circumspection. She most carefully avoids the tarantula's fangs, persists in working round to the rear of her opponent, pushes out her abdomen to full length and tries to get in a sting. Again and again she makes these rearward tactics. Nothing is so clear as her circumspection in keeping away from the tarantula's fangs.

That this circumspection means understanding is shown by a better observation from America. The Peckhams are the unquestionable authorities.[1] Their species, *Pompilus marginatus*, was accustomed to chase only quite small spiders. But, one day, after a violent struggle, she managed to overcome a huge Lycosid. Having stabbed it, what did she do next? She made a long and careful

[1] *Wasps, Social and Solitary*, p. 226.

examination of its mouth-parts. Then she began to drag it off. The Peckhams say she acted with the utmost circumspection. The careful examination of the mouth-parts of her victim indicated that she realized the power of her foe.

Intelligence in Dragging the Victim

Having paralysed her victim, the wasp proceeds to drag it. Let us look for signs of intelligent behaviour on this often difficult journey to the nest.

Many of these wasps, while dragging their victims, make a survey of their surroundings and take note of landmarks along their route. Consider, for example, *Cryptocheilus rubellus*, the destroyer of the huge tarantula. I have watched her for hours dragging her victim. She pulls it always in a fixed direction, gets her burden over obstacles of every kind, transports it a hundred yards or more. Now, this wasp must have somewhere in her mind a definite idea of the locality of her nest. Though the haul is very laborious, yet she will not deviate from her fixed direction. Then, at intervals, she leaves her victim, makes a quick flight forward, returns, and continues the haul. These forward excursions are surveying operations. She always makes them in advance of her position. When on them she investigates the objects beneath her and sees if she is on the right road. Now, what intelligence does not this imply? The area around the wasp's nest is a world of broken scrub. The wasp works, say over a hundred yards in radius. Anywhere in that area if she finds a tarantula she must drag it through the scrub to her nest. How does she do it in the maze of jungle? By the process of memorizing the country. She has previously visualized the objects that compose it, and she uses these objects along the road as signposts to direct

her course. Her knowledge is gained by seeing and memorizing. Nor is it just some vague or general kind of memory. It is a memory of each bush and tuft and clod that go to compose her area of work. I believe that she pictures her particular locality in exactly the same way as a human being pictures the district in which he lives.

Surely this is something other than instinctive. It is certainly not the blindness of automata or the vegetative behaviour of plants. We have memory, discrimination, learning by experience, all essentially intelligent acts.

This wasp, when she goes off to survey the route, has to leave her victim for a minute on the ground. Often she lets it lie just anywhere, but, if she finds a hole, she will stick it inside, or will hide it underneath a tuft of grass. The Peckhams have observed *Pompilus plumbeus* behave in very much the same fashion. Moreover, "there are degrees of intelligence among them." One will take no pains to hide her victim, another will invariably bury it in the sand before making an excursion to the nest. I can vouch for the same variability in the species studied at Baghdad.

Also these wasps, when concealing their victims, do so in the vicinity of some conspicuous landmark. They hide it near a tuft or a piece of stick, and it is clear that, on their return, they find it by recognizing the tuft or stick. Here, again, we have intelligent behaviour, establishing a landmark, memorizing it, in order to find what has been concealed. The conclusion is, to my mind, beyond question. Remove the landmark when the wasp is absent. See her bewilderment when she returns, and no doubt will remain in the mind that she has carefully memorized the act.

Intelligence in Storing the Victim

The next step is the storing of the victim. Do these wasps ever show intelligence when occupied at this important act?

The getting of the victim down the burrow is usually a simple bit of work. In the case of those species I observed at Baghdad the wasps had their nests in yawning fissures. The victims were pulled straight in. But sometimes these huntresses meet with difficulty. The opening of the hole happens to be small, and the wasp cannot get the burden through. Is she nonplussed? Not in the slightest. *Pompilus scelestus*, observed by the Peckhams, arrives with a spider that will not go in. What does she do? Cut away the entrance to the burrow until it is large enough to admit the prey. *Pompilus fuscipennis* arrives with a spider. The same thing happens, and it sticks in the tunnel. What does this one do? Pulls the spider again into the open, gives its legs a severe squeezing, then succeeds in getting it in. *Ampulex compressa* arrives with a cockroach. Again the same problem arises. How does she act? Cuts off bits from the cockroach's body until it is small enough to slip through.

All these acts are clearly intelligent, and far removed from routine behaviour. They are the result of trial and error. Something has happened. The burden has got stuck. A divergence from ordinary behaviour must be made in order to get on with the work.

But the Peckhams quote an even better instance.[1] *Pompilus scelestus* arrived with a Lycosid. Her nest opening was small. The Lycosid was large. It clearly would not go in. The wasp did not even make the attempt. She did a very extraordinary thing, one which

[1] *Wasps, Social and Solitary*, p. 238.

I could scarcely believe were it not seen by such distinguished observers as the Peckhams. She left her Lycosid a little distance from the nest, then went and had a look at the narrow opening, then returned to her victim and "measured it with her eye," then went back to the nest and commenced to enlarge the door. Here we have a neat illustration of judgment. In this case there is no trial and error. The wasp, without meeting any impediment, gets "struck with the thought" that the hole is not big enough. What must have happened in her insect mind? She must have compared two things, the size of the hole and the size of the spider, and, as a result of that act of comparison, decided that the spider would not fit.

The wasp lacks "the smallest gleam of intelligence." So says Fabre. But what does this act of comparison teach us? That the wasp can *judge* difference in sizes, that she can *reflect* on the sizes not fitting, that she can *plan out a course of action* for the purpose of making them fit.

I will give only one more illustration, again from those excellent observers, the Peckhams.[1] *Trypoxylon rubrocinctum* collects spiders and stores them in holes in walls. The male remains on guard within the hole while the female goes out to collect provisions. Their routine behaviour is very interesting. When the female returns with a spider, the male goes out in order to make way for her, then gets on to her back, and both enter the hole together. But, on one occasion, when storing was delayed owing to rainy weather, the Peckhams saw the male assisting in provisioning. When the female returned with her spider, the male, instead of following the ordinary

[1] Psyche, Vol. VII, p. 304.

routine, took over the spider brought by the female and assumed the business of packing it in the nest. This change in habit was obviously advantageous, especially in allowing the female to go off and hunt about for another victim. It is very unusual for male solitary wasps to take any part in the work of provisioning; so that here we have a remarkable divergence to meet a particular end.

Intelligence in Closing the Nest

This is the last step in the sequence. The victim is inside and the tunnel must be sealed. We can show the most convincing proof of intelligence in connection with this stage of the work.

The Pompilids, storers of spiders, often take the greatest pains to conceal every trace of their nests. *P. quinquenotatus*, having closed the opening, will put over it a small stone or, perhaps, a pellet of earth. *P. viaticus* will cover it with pine-needles, or will scatter around it a few pellets of rabbit's dung.

The *Ammophilæ*, storers of caterpillars, are equally careful about hiding their work. I have been very struck, in a Himalayan species, at the judgment with which the wasp selected her pebble, choosing one of precisely the size that would fit into the entrance of the nest. I have not seen them putting objects on the entrance; but that *Ammophila vulgaris* covers it with fir leaves is recorded by the distinguished Ray and Willubhy. Mr. Latter describes similar behaviour as "a delightful display of sagacity."[1] His species was *Ammophila sabulosa*. She had made a nest with a funnel-shaped mouth. To close it she brought a flat stone exactly the size to fit the funnel. Her choosing of the stone was done carefully. If it happened to be too big or of the wrong shape, then the

[1] *Bees and Wasps*, by Latter, p. 22.

wasp got rid of it and fetched another. Having stopped the funnel with a suitable pebble, then she concealed the whole with sand, and ended by bringing some grass roots which she scattered about the place.

If anyone questions the intelligence of these acts, what can he say when asked to explain that wonderful and delightful observation of the Peckhams? To my mind it forms the best instance of intelligence yet recorded in

FIG. 24.—*Sphex urnaria* using pebble to pound earth over burrow.

Sketched from the Peckhams' illustration.

any insect. I refer to the way in which *Ammophila urnaria* makes use of a stone as a hammer.[1]

The Peckhams watched this wasp closing her nest. She first filled the burrow level with the ground, then brought some grains of dirt to the spot. After this came the amazing act. The wasp picked up a small pebble in her mandibles and used it as a hammer to pound the grains of dirt. She hammered them down with rapid strokes, "thus making this spot as hard and firm as the

[1] *Wasps, Social and Solitary*, pp. 38, 39.

surrounding surface." Then she brought some more earth, then again picked up the pebble, once more pounded the earth into place, " hammering now here and now there until all was level."

What can we say of this kind of behaviour recorded by observers of the strictest accuracy ? In the first place the act is highly individualistic. Hammering is not the habit of the species. It happened to be the plan of this particular wasp. Surely we can say that this individual was more original than others of her race. Then again it has always been considered that the capacity to use a tool represents a fairly high degree of intelligence. The Duke of Argyll remarks that the fashioning of an implement for a special purpose is an act peculiar to man and separates him completely from the brutes. Certainly the wasp did not fashion her hammer, but she did the next thing to it ; she got hold of a suitable object and made use of it as a tool.

Another example of the hammering operation was observed by the French entomologist, Ferton. It does not display the same clear intelligence, but the act is so intrinsically interesting, that I feel unable to omit it.[1]

Ferton's wasp was *Pompilus quadripunctatus*. He saw her strengthening the wall of her nest by hammering it repeatedly with her abdomen. The wasp clung to the wall with her legs, then began to strike it with blows of her abdomen. The blows followed one another very rapidly. They were so quick that they could not be separately distinguished. Some were to the right, others to the left, still others in the middle line. From time to time the wasp stopped, turned round to judge the effects of her hammerings, then, after a short rest, took up the business of pounding again. This strange behaviour

[1] *Annales de la Société Entomologique de France*, Vol. LXXVIII, p. 416.

lasted for an hour, and, though the whole body of the wasp vibrated, yet she did not appear to get tired. The purpose, of course, of this extraordinary action was to strengthen the wall of the chamber and prevent parasites from getting through.

We have now followed these interesting creatures through each step in their established instincts. What is the conclusion? Surely that the creature is not blind and mechanical; surely that Bethe and Lefroy are in error when they speak of insects as mechanical machines, and that Fabre is nearly as far from the truth when all he grants is an unconscious prompting that has no choice what it shall do. Our chapter disproves this narrow outlook. Remember the wasp that surveyed her territory. Where is the machine that can visualize its neighbourhood and recall the host of objects that it sees? Remember the wasp that measured the hole, then ran off to look at her victim and decided that the sizes would not fit. We are a long way from the automatic apparatus that can judge and compare like this. Above all remember the hammering with the pebble. How impossible to bring it into Fabre's conclusion which sees nothing more than an unconscious prompting that has no choice what it shall do.

CHAPTER XIV

INTELLIGENCE IN MASON-WASPS

Some of Fabre's most fascinating work was his series of experiments on *Chalicodoma sicula*, a mason-bee which nested under his roof. Their purpose was to make a psychological investigation. Does the mason work as a blind automaton, or can she modify her behaviour at will? Is instinct or reason her guide? He found his *Chalicodoma* to be little more than an automaton. She can cope with just the simplest emergencies, but cannot depart from ordinary routine. Fabre will not grant her an inkling of intelligence. "O little gleams of reason that are said to enlighten the animal, you are very near the darkness, you are naught."

The masons that nested in Indian bungalows gave me an opportunity to test this. The result surprised me. I am satisfied that they are not thoughtless automata, but possess a far higher mentality than the *Chalicodoma* of Fabre.

Intelligence of the Mason-Wasp

First with respect to *Eumenes conica*. This wasp makes a cluster of cupolas on the walls and doors and windows of rooms. Her instinct consists of the following stages. First she builds a clay cell, then lays an egg inside it, then stuffs it full of caterpillars, then seals it with a lid. When one cell is finished she adds another,

and when she has built a sufficient number she covers the lot with a layer of clay. Let us test her with a few experiments and compare her behaviour with *Chalicodoma*.

Experiment 1

Fabre's bee was one of the honey-provisioners. Her business was to build a cell of clay and then fill it to the top with honey. Now Fabre played a simple trick on her. With a wad of cotton he drained away the honey as fast as the bee put it in the cell. He kept extracting it; she kept bringing it; and after this had gone on for some time the bee gave up bringing honey and closed her cell in the ordinary way. Fabre did this with a number of cells and after the experiment measured their contents. The amount was different in each cell. In one it was 3 millimetres, in two 1 millimetre in depth, in others there was no honey at all. What was his conclusion? That the instinct to provision is so blind and mechanical that the bee does not estimate the height of her store. She accumulates only so long as she feels the accumulating impulse. "She does not reason like a geometrician, she does not reason at all."

FIG. 25.—Cells of *Eumenes conica*.

Now apply this test to *Eumenes*, the caterpillar-storer of Indian bungalows. It is my intention to rob the cell

each time the wasp puts in a caterpillar.[1] The experiment begins at 3 p.m. when the first caterpillar arrives. It is a large and fleshy individual. Two or three of that pattern will easily fill the cell. She stuffs it in. I pull it out. She brings another. The same thing happens. By nightfall I have robbed her of five, a sufficient number to fill two cells. She returns next morning. More caterpillars are brought and are systematically robbed. *Eumenes* now begins to get concerned. She comes often to the cell, sometimes with a caterpillar, sometimes to inspect; obviously she is very perturbed. This goes on so long as I have leisure to watch her. In the end I rob her of nine caterpillars, then have to go away, so she stores in peace. After that I found she brought two more which was sufficient to fill her cell. Thus in all she collected eleven caterpillars, a supply more than enough to fill three cells.

Now for the conclusion. Her behaviour differs from Fabre's *Chalicodoma*. It is not only instinct that guides her. If it were, then she would have brought three or four caterpillars, the amount sufficient for one cell. Instinct then would have been satisfied, as it was in the case of Fabre's *Chalicodoma*. But it is not satisfied. She knows that her chamber is empty, and keeps on working until it is full. Her guide in storing is the quantity of provisions. She shows, at least, some little judgment in measuring the height of her supplies.

Experiment 2

This experiment concerns the young *Eumenes*. Again we will find a higher mentality than Fabre's experiment allowed him to admit.

[1] *Journ. Bombay Nat. Hist. Soc.*, 1927, pp. 890–6.

Having taken a young wasp from its prison, Fabre put it in a tubular reed. He barred the entrance with a double door, the outer one of paper, the inner one of clay. What would this mean for the wasp? It would mean that, when the time for emergence arrived, the wasp would have to perforate two barriers instead of just eating through the wall of its cell. What happened? The first barrier was a wall of earth. No difficulty about this. The young wasp went through the earth just as if it was the cell wall. But beyond the earth it was unable to go. It could not get through the paper, though the paper was far more easy to penetrate than was the barrier of earth.

Fabre supplies the simple explanation. The young wasp's instinct is to eat through its cell. That is its natural mode of escape. The completion of that act satisfies instinct, and instinct is so mechanical that the wasp cannot repeat the act. It can penetrate once, not twice. If, in the experiment, it bored through the paper, then it would perform a second time what ordinarily it does only once. Such repetition is impossible. Hence Fabre's wasp died behind the paper when just a few cuts with its jaws would have brought it to the open air.

I repeat this experiment with *Eumenes conica*. The larva, only a few days old, is transferred to a glass tube. There it develops as if in its cell. I block the tube with three mud barriers, each a formidable obstacle, twice the thickness of the cell wall. I confess I do not anticipate the result. I expect to see the wasp eat through one partition, then live on for a day or two, but fail to perforate the second wall. Nature, however, is full of surprises. This wasp is not so bound to instinct. I look one morning to see what has happened. The three barriers have been perforated in succession and the wasp has escaped from the tube.

Experiment 3

Here is an experiment that goes to prove that the wasp can judge geometrical shape.

Eumenes conica, having built her cell, leaves a circular opening at the top and surrounds that opening with an outturned rim. Now the point about the hole is that it is a circle, and one so remarkably perfect that it might have been made with a drill. Now what will happen if we meddle with this circle. Let us alter its perfect shape and see if the mason can intelligently mend it.

A cell has been built. Before us is the circle. All that remains is the rim which the wasp will make on her next visit. While she is absent getting clay for the rim, I take the chance to meddle with the circle. With a penknife I alter its shape and convert it into an ellipse. Now let us watch what the mason does. When she comes back she sees that things are wrong. Her antennæ tell her that the hole has been meddled with. We see her employing them like a pair of dividers, measuring the hole in different diameters. In one diameter they separate widely, in another diameter the divergence is less. Hence the mason knows that things are out of order and that the shape of her circle has been changed. What does she do? Just go on like one of Fabre's automatic creatures. Not at all. She does what a rational being would do. In her jaws is a pellet of mud. She has brought it for the purpose of making the rim. But now, having found what has happened to her door, she thinks of employing it in a different way. She cuts it in two pieces, puts one piece into one end of the ellipse, and the other piece into the opposite end. Then she again starts measuring diameters and touches up the edge all round. The result is that my ellipse gets reshaped into the perfect circle.

Is not this a bit better than Fabre's automaton? Why, the mason is not such a bad geometrician. Moreover, she knows that her shapes have been tampered with, and can fashion a circle out of an ellipse.

Experiment 4

While *Chalicodoma* was provisioning, Fabre made a breach in her cell. The mason was unable to close the

FIG. 26.—*Eumenes* stuffing caterpillar back through breach. Experiment 4.

rent. All she did was to keep on pushing in honey, which, of course, as quickly leaked out through the breach. Finally the wasp introduced her egg, sealed the door, but made no effort to rebuild the breach. Why did the insect act so foolishly? Why allow all the honey to escape and then close an empty cell? Fabre gives the simple explanation. The insect is controlled by rigid instincts. She must follow a psychic course, and perform her acts in an unchangeable routine. She must keep to the occupation that engages her at the moment. Hence in

the face of this glaring injury she cannot repair her cell.

Now for the Indian *Eumenes conica*. I break a hole in the bottom of her cell. The owner is absent, hunting for caterpillars. It is a huge rent. I have made it so large that when a caterpillar goes in, it is almost certain to drop out through the breach. The wasp arrives, and in goes her caterpillar. It falls through, and down to the ground. She comes with a second. This one manages to stick in the hole, but a large part of it hangs out. More are brought, and, because number two has blocked the breach, they manage to remain inside. One thing, however, is very evident. The wasp pays not the slightest attention to the breach. So far her behaviour has been quite automatic; but now, when all her caterpillars are in, some sign of enlightenment appears. At last she seems to realize the damage. She examines the breach with the caterpillar dangling through it. If an automaton, she will now be helpless. All she will do is just look at the injury and go on with her routine work. The best she will be able to do is to leave things just as they are. But watch her behaviour. She stuffs back the caterpillar, a task which she finds both difficult and prolonged. Then she makes off, fetches a pellet and builds up the breach.

I regard this as an act of intelligence, an indication that the mason appreciates difficulties and realizes how to put them right. Then why did she not repair when provisioning? Merely because she was so preoccupied She did not notice the hole. At the final survey she sees it immediately. Then she not only repairs the damage, but also pushes back the grub.

Experiment 5

If the last experiment is not convincing, here, I think

is unquestionable proof. *Eumenes conica* has made a group of cells. It is her custom, when the group is finished, to cover the lot with a layer of mud. In this experiment she is working at the cover. Egg-laying, caterpillar-bringing, all that business, has been finished for good and all.

While she is engaged at making this cover I break into one of her cells. She soon finds the hole, makes

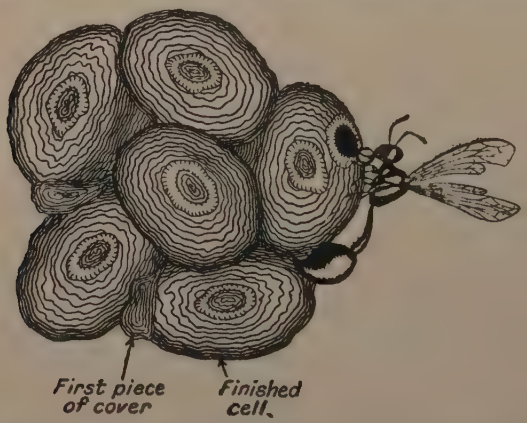

FIG. 27.—*Eumenes* making rim round hole in side of cell. Experiment 5.

no end of a fuss about it, goes off, brings pellets and repairs it in the usual way. Perhaps we might have anticipated this. The wasp had been engaged at masonry, so it is only a slight divergence to stick some mud into the hole.

But watch further. I reopen the breach. I make the hole so big that a pencil can go into the cell. In addition I pull out all her caterpillars and leave an empty cell. Here now we have a crucial test. Will the wasp, as before, just repair the hole, or will she stuff it with a fresh supply of caterpillars? If number one, then her

act is instinctive ; if number two, then she works intelligently. She will have broken from the duty of the moment and have departed altogether from routine.

Let us see. Very soon she arrives and goes on with the cover. She does not attend to the breach immediately. Not till after a dozen journeys does she begin to think about repair. But then observe her instructive behaviour. Before her is a ragged opening. She investigates it, crawls through it, and explores the void within. Then she goes and gets a pellet. With this she works at the edge of the rent and converts it into a circle. At the next visit I expect to see her close it. Remember what was her business at the time. Her business was cover-making, in other words masonry. Hence I expect nothing better than masonry, just a little clay stuffed into the hole. But when she arrives I am astonished at her actions. She goes to the hole, but does not just fill it, to my surprise she puts round it a rim. What can this mean ? This is not the time for rim construction. Moreover this hole is in the side of the cell, and rims are made only round entrances which are always at the tops of the cells. What then is the wasp's intention ? Is she going to turn my hole into an entrance ? Is she by any possibility going to replenish the pillaged stores ? Her next visit will decide the point. A long absence makes me suspicious. If collecting clay, she should be back in a minute. I do not see her for a quarter of an hour. At last she arrives, and, to my delight, I see a caterpillar dangling in her jaws. In the orthodox manner she pushes it in, then brings more, fills the cell, and ends by inserting a plug.

Now, what is this ? The wasp, when cover-making, finds a hole, and the hole leads into a pillaged cell. If an automaton, what will she do ? At best she might build in the hole, for that would still be a kind of masonry not

far removed from her cover-making business. But she does *very* much better than this. She shapes my rough opening into a circle, constructs a rim, replaces the caterpillars, and ends by putting in a plug. These are actions far outside routine behaviour. They have nothing to do with the cover-making business. The wasp is up against a new problem, and solves it in a rational way.

Intelligence of the Potter-Wasp

Turn now to another species, *Rhynchium nitidulum* of Smith. This wasp is a builder of pots, usually on the ceilings of rooms. Her routine is not unlike that of *Eumenes*. First she builds a clay pot, then covers the pot with resin, then stuffs the pot with caterpillars, then seals the pot with a lid. When one pot is finished she puts another alongside it, until in the end she has a cluster of pots.

Experiment 1

A potter has her cell three-quarters built. Every minute she is bringing clay and raising the wall higher and higher. When she is absent getting clay I make a hole in the front of her wall.[1] It is a large conspicuous rent; through it the wasp could walk into her cell. On her return she sees it immediately and seems to understand exactly what to do. In her jaws is a pellet intended for building. She diverts it from this intended purpose and spreads it round the edge of the hole. Then she goes off for more material, and keeps on working at the hole until it is completely closed.

Can we call this intelligent behaviour? Remember the wasp was engaged at masonry when I made the hole

[1] *Journ. Bombay Nat. Hist. Soc.*, 1927, pp. 246–52.

in her cell. What then is the act of repairing? Why, it is only a continuation of masonry. The potter puts her clay on the edge of the hole instead of on the edge of the wall. Well and good. If anyone refuses to admit intelligence, then I am not prepared to press the point. Nevertheless, I think that there is some intelligence. Unforeseen circumstances have arisen. The wasp sees them and clearly understands them, desists from the work on which she is employed and straightway puts them right.

But, I admit, the routine of instinct is unaltered; so let us experiment a little more.

Fig. 28. — *Rhynchium* trying to mend hole in pot with resin. Experiment 2.

Experiment 2

A pot is built; the egg is inside; and the wall has been smeared with resin. I make a hole in the bottom of the pot, and wait to see what will happen. The wasp arrives, sees the big hole, makes a careful examination of it, and then tries to mend it with resin. She pulls bits of resin from the wall of her pot, and smears them along the edge of the hole. It was amusing to witness her efforts, the complete hopelessness of the attempt to close a gaping hole with gum.

Why did she do this? The explanation is simple. The wasp had just finished smearing resin when I made the hole in her pot. Resin-smearing was the business of the moment; hence, when she finds my hole, her instinct is to smear it with resin. For two hours she keeps trying to do it. Night arrives, and nothing has been effected. The big hole is still in the bottom of her pot.

So far, blind futile instinct. But wait. See what happens on the following morning. The wasp spends the night in her pot. Next morning she leaves it early, and, on her first return visit, again carefully investigates the hole. She goes off a second time and brings back a pellet of mud. Entering the cell through the hole, she sets about repairing the damage. First she works at the edge of the hole, fills in all the little irregularities, until my ragged opening is converted into a uniform circle. Then she closes the circle with a lamina of clay, which she manages to neatly curve into the natural rotundity of the pot. Nor is she content with just a patch of mud. Off she goes, fetches resin, smears it all over the patch until it blends with the rest of the pot.

Surely this act implies intelligence. It is a display of individual resource. Nor must it be imagined that the wasp was misled, that she confused the repair of a hole with the ordinary closing of a gate. For she did her repair in a different manner. When closing the gate, she sits outside and from there introduces clay. When repairing the hole, she examined it from both sides, and then, having made a choice, elected to do the repair from within. This, to my mind, is clear ingenuity. First she attempts to repair with resin. This is futile ; it is mere instinct ; just a sticking to the psychic course. A night's rest brings a change in outlook. The wasp then breaks from the bondage of her instinct, attacks the difficult problem intelligently, and repairs the damage with complete success.

Experiment 3

Here is a more convincing case. The potter had finished a cell six weeks ago. A young wasp had emerged from it, and the parent had made use of it a second time. For the last three weeks she had been busy provisioning it,

during which time she had done no masonry except for two small pellets which some days ago she had used for the lid.

Now, here we can make a crucial test. The potter is finished and done with building. Clay-bringing, plastering, everything of that kind, must be, therefore, out of her mind. Can she then deal with a particular emergency which requires plastering to put it right ?

As before, I make a hole. First I make just a small perforation no larger than a pin's head. Later in the day the wasp discovers it, goes to the trees, gathers resin, and plugs my small hole. I then make a larger breach, one which she cannot repair with resin. See what happens. Remember that for days she has done no masonry, that the last act which she performed was to mend a small hole with resin. Yet, in spite of this, she is not disconcerted. Off she goes, collects clay, and builds a patch into the breach.

Surely the act demands intelligence. There is nothing routine about this kind of behaviour. The wasp understands the problem before her. She appreciates the relation between cause and effect, and this stamps her as a rational being.

Let us sum up these three experiments. We have put before the potter a particular problem at three different stages in her work.

1. She finds a hole in a three-quarter built pot. What does she do ? Repairs the hole. Even this, I think, requires some intelligence. The wasp must appreciate what has happened, and must halt in the progress of her work in order to make the damage good. However, I do not press the point. There was no change in actual routine. The wasp at the time was engaged in plastering, and mending, after all, is a kind of plastering. The wasp placed the mud on the rent instead of on the edge of the wall.

2. She finds a hole when smearing resin. What does she do? Begins by sticking to routine behaviour, and tries in vain to fill the hole by putting into it bits of resin. In time, however, this behaviour changed. She gave up smearing resin and built clay into the breach. Here we have intelligent behaviour, a recognition of the nature of a problem, and a complete alteration in routine.

3. She finds a hole in a pot that was finished six weeks ago. For days she has done no plastering. One might think that she had forgotten her pot. But no. The result is the same as in the previous experiments. She fetches clay and builds in the hole.

Surely the meaning of it all is this. A hole is made in the architect's pot. A new experience is put before the wasp, something she has never met with before. She sees what has happened and deals with it efficiently. Had she done so only when employed at masonry, then I agree the act is instinctive, what I might expect from a living machine. But the facts are altogether different. It matters not what the wasp is doing, whether she is plastering or smearing or provisioning, as soon as she finds a hole she repairs it in some suitable way. The point is that she does so on all occasions, sometimes slowly, sometimes injudiciously, but in the end does so efficiently and makes the damage good. There is only one conclusion. The potter understands the meaning of the problem, and deals with it in a rational way.

Intelligence of Bramble-Bees

The Bramble-Bees or *Osmiæ* nest in all kinds of places, in hollow trees, in the cells of other bees, in holes in wood, tunnels in walls, heaps of stones, empty snail-shells.

Now the bee, in these very different situations, makes use of the space to the best advantage. Take a hollow

stem and a cavity amongst stones. The nature of the space is completely different, yet a bramble-bee, in a hollow stem, will place her cells in a straight line, while the same species, when amongst stones, will heap them in an irregular lump. Still better, take an *Osmia* nesting in a snail-shell. When working in the narrow whorls of the shell she will place her cells in single file, but when she comes to the larger whorls she will spread them side by side. Thus their building capacity is highly adaptable. They can fit in with the countless conditions that chance and circumstance happen to supply. They possess what Bouvier calls a "flexibility of architectural genius."

But there are some special points worth mentioning in respect to those species that nest in snail-shells. Some kinds possess a most interesting habit. The mother bee makes her nest in a snail-shell, then she grips the shell with her claws and carries it away to some suitable hiding-place. Now the surface of a snail-shell is smooth and slippery, not an easy object for the bee to grip. So what does she do? She spreads over the surface of the shell a paste made out of chewed-up leaves. This paste is distributed in small patches. Its effect is to make the smooth surface rough. It gives the bee something to grip.

But see her prudence in this valuable instinct. Ferton found *Osmia rufigastra* nesting in a shell of unusually small size.[1] And on it was only a little of this paste. Why had the bee used only a little when her instinct is to use a lot? Because in this case the shell was small, in other words only a light burden on which little gripping material was required.

Then, again, he says of *Osmia tunensis* that she knows how to pick out snail-shells which happen to be coated

[1] *Annales de la Société Entomologique de France*, Vol. LXXXIX, p. 339.

with spots of mud.[1] She takes them in preference to shells that are clean. Why? Because when the cells are coated with mud she need not expend her own special paste on them. The mud gives her a gripping surface. She saves both material and time.

Now, these are not merely instinctive acts. They are acts that must be accompanied with consciousness, and that need for their performance discrimination and judgment.

Architectural Foresight

I feel inclined to give one more observation. If a wasp can prearrange her plan of architecture, then she must possess both foresight and judgment. And that, of course, implies intelligence. But can a wasp do any such thing?

Another of these masons, *Eumenes dimidiatipennis*, will enlighten us on this interesting point. Her nest is like that of *Eumenes conica*, the cells being similar in size and shape. But *dimidiatipennis* arranges them differently. She often puts them in a long line instead of an irregular heap.

One morning, in a deserted house, I happened to see on a whitewashed wall an example of this mason's work. The wasp had completed two of her cells and was about to commence the third. But here is the point which literally amazed me. In addition to the two completed chambers, the wasp had mapped out the scheme of architecture for all the subsequent cells of her nest. Before me on the wall was a definite plan, a mapping out of the final structure, made, I have no doubt, for the same purpose that the human architect maps out a house. The wasp, by means of ridges of mud, had fixed the position of all the cells which would ultimately

[1] *Annales de la Société Entomologique de France*, Vol. LXXXIX, p. 342.

compose her nest. These ridges were elongated flakes, vertical on one side, shelving on the other, in fact a series of foundation stones arranged in a long line. There were thirteen of these little flakes mapping out the thirteen more cells that the mason intended to build. What, therefore, had the wasp done? She had laid out a series of landmarks on which to found her completed architecture. At the very commencement of her labour she had prearranged for the whole work.

This, I am confident, implies intelligence. Her instinct is not limited to a single chamber. She can see in advance the plan of architecture, can calculate the respective position of compartments, can form an idea of the finished work.

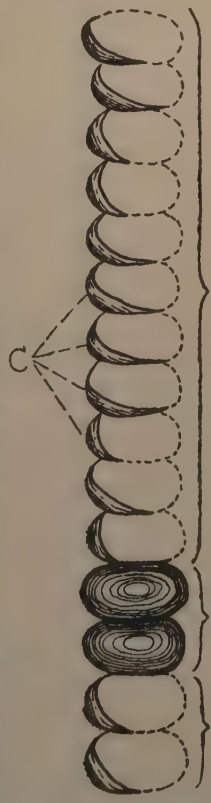

FIG. 29.—Architectural Foresight of *Eumenes dimidiatipennis*.

a. Completed cells.
b. Outlines of later cells.
c. Foundation-ridges of later cells.

We have studied minutely the mental force which guides the building of these cells and pots. What is that force? Mainly, of course, instinct. It is instinct, the inherited impulse, which directs the chief essentials of the business. But not instinct only. I have tried to prove that there is something more, that there is the capacity to appreciate new experiences, the power to generate new thoughts, in fact the possession of intelligence and reason.

CHAPTER XV

INTELLIGENCE IN OTHER INSECTS

Let us turn to other Orders. Admittedly they do not approach the Hymenoptera. But even so, we shall discover some indication of intelligent behaviour.

Examples from Beetles

First an example from the rollers of dung balls. I have already described their method. *Gymnopleurus miliaris* works in pairs. Two, in combination, fashion a sphere, roll it off, and bury it underground.

Now Fabre made a simple experiment.[1] His species was *Scarabæus sacer*. As the beetles were rolling their ball, Fabre drove a pin through the sphere and nailed it down to the ground. What did the beetles do? They began by trying to push the ball. Then they thrust themselves underneath it, and, by a process of elevating their bodies, hoisted the pellet clear of the pin. It seems, of course, remarkably ingenious, but, as the distinguished observer points out, there was nothing really intelligent in the act. This hoisting business is one of their instincts. It is the mechanism they habitually employ when, for any reason, their ball gets checked. In pushing the ball free of the pin, they were doing only what they always do when the ball comes up against a stick or stone. And that, says Fabre, is the height of their intellect. Hoisting is

[1] *The Sacred Beetle*, pp. 18–23.

instinctive. Hence they can do it. But they cannot initiate anything new.

Let us see if this really is the case. My species is *Gymnopleurus miliaris*, a roller of dung-balls on the Plains of India. I begin by repeating Fabre's experiment, and I get the same result. Then I make a modification. Instead of nailing the sphere with a pin, I use a long slender stake. The difference is this. The head of the pin gets buried in the pellet; there is an inch of stake projecting through the top of the ball. With the pin the beetles have no clue to the obstruction: with the stake they can see what prevents them getting on. Now watch what the insects do. It completely contradicts Fabre's assertion that all they can do is stick to their instinct. On the contrary, they show deliberation and judgment. First they make a brief attempt at rolling. Then, finding that the ball will not go forward, they go straight to that part of the stake which projects through the top of the sphere. It is astonishing to see the way that they go direct to the seat of the trouble. Into the ball they stick their heads, dig down on either side of

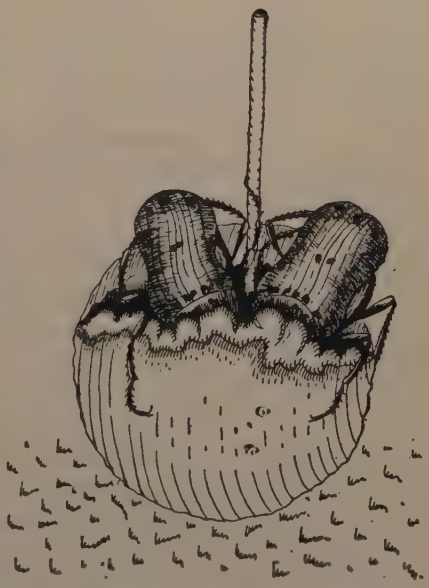

FIG. 30.—Beetles dealing with staked ball.

the stake, and extend the furrow outward until the ball is cleft in two. The two halves then fall apart, and the stake is left like a mast in the earth. Then the beetles pull the halves together, mould one on to the other and refashion the original sphere.

How can we explain this behaviour? This is not a sticking to everyday experience. The staking of their pellet is a new event, something quite out of their ordinary lives. Nevertheless the beetles understand it. They know that the stake is the cause of the trouble, and put matters right by rational means.

The view so completely contradicts Fabre that it requires further confirmation. This time I fix a stake in the ground, then lift up the ball and place it on the top of the stake. The beetles remain clinging to the ball which I press down until the top of the stake penetrates to about the centre of the sphere. Here is another quite new experience. The pellet is now an inch above the ground. Such a thing has never happened before. Yet see how cleverly the insects behave. They go straight to the under surface of the ball, to the point where it is pierced by the stake. Then, as before, they split it in half. The two pieces fall to the ground; the beetles fall down with them, and mould them once more into a ball.

Just one further confirmation. For these are remarkably intelligent acts. I suspend their ball as if it were a pendulum. The plan is simple. First I push a stake into the ball, then suspend the stake by a piece of string from an overhanging twig. The ball becomes the bob of the pendulum which can swing freely clear of the ground. Now, let us see what the beetles do. From the ground they can just reach the ball. The moment they touch it, it swings forward, then swings back on them again. Here there is no problem of inertia, nothing to make the beetles believe that their ball has happened to get

fixed. Thus, for some minutes, they keep trying to roll it. It swings forward a little way ; then swings back. There is plenty of effort, but nothing is achieved. The beetles are puzzled. They stop pushing, climb up on the bob, and soon come upon the stake by which the pellet is fixed to the string. Then they act as in the previous experiments. They cut the pellet on each side of the stake. The separated portions fall to the ground, and the ball is freed from the string.

When we try to interpret insect psychology we enter on difficult ground. But how can we call these acts instinctive ? What does the rolling instinct consist of ? First, a pushing forward of the ball ; second, a hoisting upward of the ball if it should happen to come to a stop. Did the beetles just stick to that instinct when I put before them the pendulum problem ? Certainly not. They began instinctively, trying to push. Then they changed to intelligent behaviour and cut the pellet free from the stake.

Though Fabre refuses to grant intelligence, yet his own observations include some incidents which can scarcely be regarded as anything else.

Take, for example, their powers of repair. I have stated in an earlier chapter that I halved a ball and the beetles repaired it. I cut it in four, and they brought the quarters together. I squared it, I flattened it ; they remoulded the shape. All this implies a capacity to mend.

Fabre observed that they were able to repair the cases which enclosed their eggs. These cases are made of comminuted dung. In one that belonged to *Copris hispanus* Fabre made a small hole.[1] The mother *Copris* was not at a loss. She scraped some bits of dung from

[1] *The Sacred Beetle*, p. 158.

the egg-case, and used these scrapings to mend the hole. This seemed something which Fabre did not expect. He stood "amazed at the insect's skill." He gashed another open with a penknife. In a short time the breach was so neatly repaired that not a trace remained of the onslaught. Even the grub possessed some of this skill. Fabre perforated a case that contained a young grub. The embryo pushed its hind end into the hole and injected excrement over the breach.

Here is an instance from another family.[1] Beetles belonging to the genus *Eupsalis* have their mouths drawn out into a long beak admirably adapted for boring into trees. But it has been observed that, when they are boring, the females are apt to get into difficulties. Their beaks become stuck in the woody tissue. The result is that they are helplessly fixed. Then what happens? The males come along to their assistance, and by a process of levering, pull them out.

I have said repeatedly that the power to learn must imply some intelligence. This has been noted in a water-beetle by so unquestionable an authority as Forel.[2] He kept a *Dytiscus marginalis* in a bowl, and in the end it learnt a little. Instead of retreating when he entered the room it jumped out of the water and seized what he gave it, even taking pieces of food from his fingers.

Examples from Butterflies

To begin with, butterflies are easily tamed. We have this on the authority of Mr. W. G. Wright in his work on the Butterflies of the United States. A day or two

[1] *Cambridge Nat. Hist.*, Insects, Vol. II, p. 296.

[2] Quoted by Bouvier in *Psychic Life of Insects*, p. 113.

is sufficient for the taming. The insect will then walk to you, wave its wings in pleasure, and unroll its tongue in expectation of food. This indicates, without question, some slight capacity to learn.

Then I think that certain butterflies, when laying their eggs, show that they possess the power to choose. Take the Indian Swallowtail, *Papilio erithronius*. It lays its eggs on orange and lime trees, but does not scatter them indiscriminately. The female, in the first place, picks out the young shoots, then again she puts only two or three eggs on each separate tree or bush. When watching her we see that she carefully *chooses*. On each occasion she waits and hesitates, clearly taking some moments to decide if her egg should go on that particular leaf.

Then we have certain species in Britain which seem to choose with the same degree of care. *Chrysophanus phlæas*, the Small Copper, lays her eggs on patches of sorrel. But we see signs of selective behaviour. She puts only one egg on each plant, tries first to fix it underneath the leaf, but if this is inconvenient, she fixes it on top. *Polygonia c-album*, the Comma Butterfly, patronises the gooseberry and currant. The female goes about her egg-laying discriminately. She will often examine the whole of the bush, or even investigate several bushes, before making up her mind. Sometimes a prolonged inspection will not satisfy her, and she goes away without leaving the egg.

I do not advance these details of behaviour as an indication of much intelligence, but there is something behind these inspectings and choosings which instinct cannot explain.

Examples from Caterpillars

A caterpillar is only a self-feeding embryo. Yet even these creatures have some intelligence. In fact, it is a

remarkable thing that the mental capacity of the embryo is higher than that of the full-grown form.

The common Small White Cabbage Caterpillar can crawl with ease on a rough object. But if it has to crawl on a slippery surface, then it manufactures a special device. Take, for instance, a sheet of glass. When the caterpillar gets on to the glass it begins to make a ladder of threads. It gives out silk from the glands in its mouth, spreads loops from side to side, makes a rough surface on the glass up which it is able to ascend. It reminds us of the way Honey-Bees behave when forced to work on a sheet of glass. They first place spots of wax on the glass which form points which they can grip. I have seen the same principle adopted by Termites. Workers of the genus *Coptotermes* are sometimes obliged to cross smooth surfaces; for instance, they may have to climb over a bottle. On such occasions they cover the surface with their excrement, in order to give them something to grip.

The caterpillar of a Japanese Saturnian Moth, *Dictyoploca japonica*, spins a cocoon in the form of a net.[1] Ordinarily the net is open and square-meshed, but make the caterpillar spin against glass and that part of the net in contact with the glass will be made of closely woven silk. See the excellent adaptation. On a glassy surface it makes a carpet; on a rough surface an open net. Clearly some kind of discernment must exist, some idea that the different surfaces demand a different kind of work.

What seems like a capacity to judge is seen in the caterpillar of the American Hag Moth.[2] This caterpillar

[1] *Journal of Experimental Zoology*, Vol. XLVI, p. 249.

[2] *Insects affecting the Orange*, by Hubbard. Washington, 1885, p. 143.

spins its cocoon in trees. Moreover, it puts it in such a situation as to harmonize with dead leaves and twigs. But if it cannot find this situation, if twigs and dead leaves are not available, then it does something of striking sagacity. It actually manufactures a suitable situation by killing the growing leaves. Several caterpillars combine in the operation. They chew into the bases of the leaves. As a consequence the leaves bend and wither, and in this now suitable environment the insect constructs its cocoon.

Another good example comes from India.[1] *Catopsilia crocale* is a common butterfly. Its caterpillar possesses the unusual capacity of being able to jump well. Mr. Bell, who worked out the history of the species, brought home some of these caterpillars on their food-plant. The stem of the plant was placed in a bottle, and the bottle in the centre of a basin of water. Now, one of these caterpillars wanted to pupate. As a result it tried hard to escape from its isolated place on the food-plant. Several times it crawled down the bottle, but, of course, could not cross the water. In the end it decided to jump. From the food-plant it cleared the basin, a distance of 8 inches or more. Mr. Bell concludes that this fact "argues a certain thinking power in this particular caterpillar." It was a very unusual feat. Other individuals, in similar circumstances, walked straight into the water and got drowned.

Examples from Cockroaches

Even cockroaches show some trace of intelligence. There is reason to believe that they learn from experience.

[1] *Journ. Bombay Nat. Hist. Soc.*, Vol. XXII, p. 519.

Everyone knows that they shun light and like to keep in the darkest places. Mr. Turner used this habit to test their mentality.[1] He divided a cage into two chambers, one dark and the other light. In it he placed a number of cockroaches, which, of course, were attracted to the dark compartment. Then inside it he arranged an electrical apparatus, the effect of which was that if a cockroach tried to go from the light chamber to the dark chamber it got an immediate shock. He observed that the insects were quick to learn what would happen if they tried to go into the dark chamber. Moreover, what seems rather peculiar, the males learnt more rapidly than the females.

Examples from Termites

If Termites had been studied as carefully as ants, there is little doubt that we should find them possessed of not a little judgment and resource. I will quote only one example which Beaumont noted in Central America.[2]

These insects, like many of the true ants, possess two separate castes. There are workers which do the building operations, and soldiers which take on the duties of defence. The workers' habit is to build tunnels, and travel underneath them from place to place. When the tunnel gets broken they quickly mend it with pieces of earth and a moistening of saliva. Mr. Beaumont saw one of these tunnels, belonging to the genus *Eutermes*, running across a wooden post. He broke a bit out of the tunnel, leaving a gap three-eighths of an inch long. Then he caught a black ant and pinned it in the centre of the gap. Now, see what happened. First a number of soldiers arrived and made an examination of the pinned

[1] *Psychic Life of Insects*, Bouvier, p. 112.
[2] *Trans. New York Acad. of Sciences*, Vol. VIII, p. 95.

ant. Following these came a party of workers. These latter set about burying the ant. Over it they heaped a quantity of sand which they had moistened with salivary secretion. The result was to encase the ant and glue it down firmly to the post. Then they set about repairing the tunnel. But they did not just follow their previous method and connect up the original gap. No. They made an adaptation to the changed conditions. Their new tunnel, instead of being straight, was curved into a semicircle. The creatures had made a special deviation in order to escape the offensive ant. Can anyone maintain that they did not know why they made this particular curve?

FIG. 31.—How *Eutermes* repaired tunnel after ant was pinned between broken ends. *Sketched from an illustration by Mr. Beaumont.*

EXAMPLES FROM SPIDERS

What does Fabre say of these creatures? "Neither weavers nor spinners know how to repair their work. These wonderful manufacturers of silk-stuffs lack the least glimmer of that sacred lamp, reason, which enables the stupidest of darning-women to mend the heel of an old stocking." Fabre is distinctly nearer the point when he makes these remarks in connection with spiders. Admittedly they have the most wonderful instincts, but only once have I met with an act which appeared to demand intelligence. This was the power of certain species to mend holes in their cocoon-chambers.

The observation is from Central India.[1] Certain spiders

[1] *A Naturalist in Hindustan*, pp. 153, 154.

there bend blades of grass in order to make chambers for their eggs. One kind bends the blade into a triangle; another kind twists it into a spiral. Whichever type it happens to be, the spider remains inside with her eggs. I cut a window in the wall of a triangle. The spider comes to it, makes an inspection, and seems to realize what has taken place. After a delay of no more than a minute, she twists her belly round to the window, oscillates it from side to side, and attaches a thread at every swing. This goes on in a steady manner until the window is closed with silk. I do the same with the spiral chamber, and cut a piece from the central coil. Next day I return to see what has happened, and find that the breach is completely closed.

FIG. 32.—Spider mending window in triangular chamber.

This implies that the spider can appreciate the injury, also that it knows how to put things right. I do not claim for it very much, but I see in it the skill of the darning-woman who repairs the heel of an old stocking.

Such is the one example of intelligence that has come under my own notice. Other observers have been more fortunate. They have met with incidents which, I think, must require a little judgment. Darwin saw an Epeira at Rio de Janeiro which varied its behaviour according to circumstances.[1] As is well known, the habit of these

[1] *Voyage of the "Beagle,"* p. 38.

spiders is to drop to the ground when disturbed. This species followed the accustomed habit if there happened to be undergrowth beneath its web. But if the ground was clear of undergrowth, then the spider did not drop; it ran through a central passage in its web in order to get to the other side. There must be some little judgment in this. The advantage in the act of dropping is that the spider gets lost in the undergrowth. Hence the creature must alter its tactics in accordance with the environment of its snare.

Another example is equally authoritative. Belt saw a Phalangid, or false spider, in the midst of an army of Eciton ants.[1] These Phalangids have very long legs, and the one observed by Belt seemed to have manipulated them very judiciously. It stood quietly amongst the marauders, and lifted its long legs, one after the other, above its body out of reach of the ants. It acted with the "greatest circumspection." Sometimes five out of the eight legs would be lifted at the same time. Whenever an ant approached a leg, then that leg would be lifted up, and another put down in a clear space. Again I think we must admit some prudence in this method of escaping the ants.

Spiders have been said to employ a pebble to ballast a web which happened to get loose. I would still be sceptical of this observation were it not supported by Fabre, a witness so hostile to admitting intelligence. His species was *Clotho Durandi*.[2] It makes a web like an upside-down dome, about the size of half an orange.

[1] *Naturalist in Nicaragua*, p. 19.
[2] *Life of the Spider*, pp. 343–5.

The architect hangs things under its dome in order to keep the structure stretched. Bits of earth, sand, gravel, wood, anything that happens to lie about, will serve this purpose of ballasting the dome. The spider seems to understand the object of the ballasting. For when the ballast is cut away it fetches more and hangs it to the dome. The act, though suggesting some idea of mechanics, is, perhaps, nothing higher than Fabre's *Discernment*. But it lessens our doubt of other observations which credit spiders with mechanical understanding. I refer to a spider suspending a stone from a web which was insufficiently stretched, and to another which fixed a pebble to a thread which happened to break loose.

I think it is clear that we find traces of intelligence in many of the less advanced forms of insects. Even butterflies and cockroaches can learn from experience, and that requires something in addition to instinct. Beetles undoubtedly possess intelligence, though the view is strenuously denied by Fabre. Of the Burying-Beetles he asks the question: "Have you within you the humble germ of human thought?" What is the reply? That the creature "has no guide but the unconscious promptings of instinct." I cannot speak for the burying-beetles. But with respect to the rollers of balls, they give quite a different answer. We have seen in a variety of ways that they possess discrimination and judgment.

CHAPTER XVI

INSECT MEMORY

We have said that the best way to demonstrate intelligence is to try if the creature can learn a little. If it is able to learn some lesson, then it must make some new mental adjustment. Its mind must acquire something fresh. Through learning it gains something which it did not have through heredity.

But in order that an insect should learn a little it must possess some trace of memory. It must remember its lesson before it can repeat it. I have already shown that insects can learn. It is necessary to prove that they possess memory.

Evidence from Wasps

Nothing is more clear than that solitary wasps remember the sites in which they make their nests. They form a mind picture of the objects in the neighbourhood and recognize those objects when they see them again. This implies that they possess memory. They remember the picture that they once saw.

Many incidents give proof of this. First we have the trouble that these wasps take to study the objects round about their nests. This delightful little trait of individual behaviour has been seen all over the world. When a *Sphex* completes her burrow she circles round it a number of times, first making small circles, then making wider

ones, systematically and thoroughly examining the surroundings until she has fixed the locality in her mind. I have often seen this take place in India. The Peckhams observed it repeatedly in America.[1] For instance, they say of *Sphex ichneumonea* that she circled five times around the spot, studying in detail every little object and getting her bearings before flying off. The Peckhams made tracings of these locality studies, convincing evidence of the great care which the wasps take to note every point. For the study is a kind of geographical inspection. The wasp is making a mind picture of the place. She will remember it on her return.

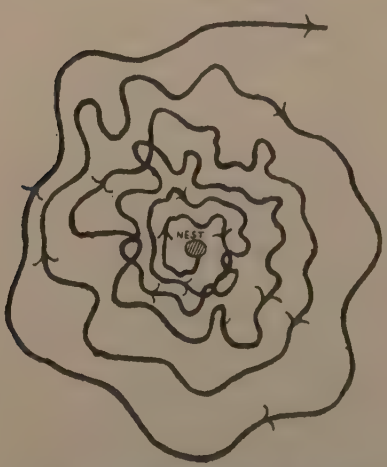

FIG. 33.—Locality study of Sphex.
Taken from the Peckhams.

Bates reports the same from the Amazon.[2] His wasp was *Monedula signata*, which digs a solitary tunnel in a sandbank. Before leaving the tunnel she makes circles in the air, then goes away half a mile to the forest in order to find the necessary prey. She returns, alights on her tunnel with the greatest ease, though there seems to be nothing to guide her on the sand. Bates was convinced that she took her bearings, and that the mental operation involved was essentially the same as what takes place in man.

[1] *Wasps, Social and Solitary*, pp. 58, 59.
[2] *Naturalist on the River Amazon*, pp. 195, 196.

We have similar evidence from Professor Balfour-Browne.[1] He experimented with *Osmia rufa*, one of our British species. He got the bee to nest in a tube, then watched to see her locality study. She flew backwards and forwards in front of it, obviously noting the different landmarks. Her flight began by an inspection of the entrance, then she extended it farther on each side, then she went indoors or disappeared for a little, then returned and repeated the flight. Her study lasted fifteen to thirty seconds, and it was clear that some individuals learnt more rapidly and accurately than others.

There is an interesting way of confirming these facts. For instance, when a wasp has no intention of returning, she neglects to make a locality study. A *Sphex* sometimes begins a nest, but for some reason does not finish it. She goes off, but neglects to make circles in the locality. They are not necessary for her purpose. The nest does not suit her. She will not return.

Hive bees make these locality studies. When they go off on their first flight they study the door, the hive, the surroundings, and in this way learn the geography of the place. But what happens if this duty is neglected? We can guess from an experiment known to bee-keepers. Take some bees from a hive to a great distance. Release them. They immediately return. But take from the hive some young bees which have not yet made their first flight. Carry them only a short distance. Set them free, and they are quite lost. They perish. Since they have not made the locality study they are unable to find their way back.

All this concerns the departure from the nest. Let us now look to the insect's return. The usual thing is for a solitary wasp to go straight to her nest without any hesitation. The precision of the act, which we ascribe

[1] *Concerning the Habits of Insects*, p. 45

to memory, often surprises us by its perfection. There is, for example, *Monedula signata*, which Bates saw digging tunnels in sand-banks. She had to go half a mile for provender, yet on her return went straight to the tunnel. How did she find the exact spot in that uniform waste of sand? Or think of the accuracy of *Trypoxylon rubrocinctum* which the Peckhams saw nesting in the straws of a straw-stack. The stack was 240 square feet in expanse. It had been cut smooth on one side, and thousands of cut ends of straws were exposed. The wasps brought spiders to these cut ends. Each stocked her particular straw. How did she recognize it? How did she pick out her individual straw from the thousands of similar ones around it? We can only ascribe it to a marvellous memory, in some ways far more certain than our own.

An interesting point brought forward by Ferton shows how the working of a wasp's memory must be something like that of man.[1] If a man is engrossed in some particular work, his memory is likely to lapse. The philosopher, for instance, absorbed in a problem forgets that it is time to go to dinner. Now the same thing occurs in the insect. Preoccupation brings a lapse of memory. Here is the proof. *Ammophila hirsuta* captures caterpillars. Ordinarily she finds her nest with ease. Memory brings her straight to the door. But when burdened with a heavy caterpillar, then she has trouble in finding the entrance. If she drops her load, the difficulty ends. She goes straight to the nest entrance. When she picks up the load she again gets confused. Her trouble in finding the spot returns. What is the reason? With a light load the wasp's mind is untrammelled. When the load is heavy she is very pre-

[1] *Annales de la Société Entomologique de France*, Vol. LXXIV, p. 96.

occupied. Her attention is absorbed in energetic effort; hence she cannot fix it on other things. It suggests that the psychic phenomena of the insect do not differ in essential character from those which take place in the human mind.

Now, if wasps really observe and remember (for the matter is denied by distinguished authorities), what will happen if we alter the arrangement of things when the insect is away from her nest? If she really studies landmarks, what will she do when the landmarks are changed? Many experiments enlighten us on this point. I will give just a few from diverse species.

Psammophila tydei, a caterpillar-hunter, pushes her trade in the Himalaya. I saw her make a tunnel underneath a leaf, then go off to look for a victim. In her absence I broke off the leaf. She returned, having failed to catch anything, and tried to get into the nest. Under ordinary circumstances she would enter immediately, but now she seemed lost in the absence of the leaf. She wandered about, searched everywhere. After five minutes she was still outside. I replaced the leaf. Her difficulties ended. She went straight underneath it and into the nest.

Bouvier experimented on *Bembex labiatus*. He cut away the plants around her nest, clearing a space of 30 square inches. The wasp on her return was much confused and flew about for a long time before finding the way in. On another nest he placed a flat stone. The wasp got accustomed to this new object, and went into her nest by going under the stone. He then shifted the stone to a distance of 8 inches. The wasp, on her return, was confused by the shift. She went to the spot where the stone had been moved to, and persisted in trying to get underneath it.

But the best experiment was made by Ferton.[1] His

[1] Quoted in *Psychic Life of Insects*, Bouvier, p. 110.

bee was *Osmia rufohirta*, whose habits are well suited to these memory tests. This bee nests in an empty snail-shell, then rolls the shell over the ground in order to hide it in some special nook. The bee finds a shell situated at A. She rolls it over the ground to B. She leaves it at B, flies away to M in order to get material to close it. In ten minutes she is back with material. But see the course of her return journey. Instead of going direct to B, she goes first to A, then to B. Again she goes off to M for material. In her absence Ferton moved the shell to C. How does the bee return to it now? She goes first to A, then to B; finding nothing at B, she searches round and in the end comes on C. Again she goes off to M for material. How does she return? By the route A-B-C. The bee now tries to put things right. She rolls her shell back to A. Again she goes for material to M. How does she return? Not direct, but by the route A-B-C-A, though she sometimes neglects B where the shell remained only a short time. The shell is now transferred to D. Again the bee goes off for material. How does she return? By the route A-C-D. She has already forgotten B. Later she begins to forget A, and goes by the route C-D.

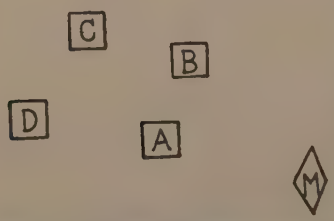

FIG. 34.—Ferton's experiment on *Osmia rufohirta*.

Thus we see in the clearest possible manner that the bee retains a memory of places. We observe that her memory is exact and tenacious. Also we see how the memory of places seems to get gradually lost. How can we think insects behave as automata when we see them guided by these acts of memory, so far as we can judge essentially the same as those which operate in the mind of men.

How long does this memory for the nest last? Certain bees, like *Bembex*, have bird-like habits. They keep feeding the larva while it is developing. Hence they must retain the nest memory so long as the larva requires food. Young bees remember the place where they were born. Hatch out some *Osmiæ* in glass tubes. The young bees, when they leave, will remember their birthplace. Memory will bring them back to the home, and more than likely they will nest in the tubes. But I think we can go a much further step. I suspect that the wasp, *Rhynchium nitidulum*, remembers her nest from year to year. In May I see her build a cluster of pots on the inside wall of an Indian bungalow. Through the whole of the hot season she sticks to those pots, a constancy which we seldom find. Winter supervenes. *Rhynchium* disappears, probably goes to sleep in some hole. Nothing happens till the next year. April arrives. Unexpectedly I see the old nest reoccupied. *Rhynchium* has come back to it, swept it and repaired it. I feel sure that the foundress of the previous season has returned to her old home.

We have written enough about nest memory. Let us see if wasps remember other things. They certainly remember where they leave their captures. *Cryptocheilus rubellus*, the Tarantula huntress, often has to leave her capture for a minute while she goes off to survey the route. She never does so without making a locality study. I have never known her neglect the duty. She fixes in her mind some particular landmark which will lead her back to the abandoned prey.

There is no doubt that she does fix a landmark. Belt settled that point many years ago. His wasp was *Polistes carnifex*, one of the social species of Nicaragua.[1] She had found a caterpillar, carried off half of it, but left the

[1] *Naturalist in Nicaragua*, pp. 105, 106.

remaining half on a plant. Before leaving, she made a locality study. She intended to return for the other half. Back she came, but had trouble in finding it. In her search she got lost amongst the leaves. Then she came outside, made a circle and pounced down on the spot where she had first gone in. Belt had noted two small seed-pods close to the spot where the wasp had entered. These were the landmarks he had taken. Now the wasp had done exactly the same. Each time she flew in to look for her caterpillar, she first dropped directly down on the seed-pods, then ran inside to search amongst the leaves. She came out again, made another circle, again dropped down on the same seed-pods. The point was the way in which she made for this landmark. Whenever in her circles she came in sight of it, down she pounced, alighted close to it, and recommenced her quest on foot. She did this half a dozen times, and in the end came upon her caterpillar. Belt expresses wonder that an insect should use a mental process so similar to that of man.

Bees certainly remember food. This is obvious from the fact that a marked individual will come repeatedly to the same spot. But their memory is long-enduring, far more so than we might imagine. They can certainly remember for forty-eight hours. If bees are given food on a particular day, and the following day happens to be thundery, then they may not go abroad on the thundery day, but will come to the food all right on the morrow.

But bees can do far better than this. There is the well-known observation of Huber. One autumn he put some honey in a window. The bees visited it in large numbers. During the Winter the honey was removed, and shutters were closed across the window. When Spring came the shutters were opened. Then the bees again arrived, though there was now no honey in the window. Just as *Rhynchium* remembered her cell throughout the winter,

so can honey-bees remember the place where they happened to find food.

What conclusion can we draw from this variety of observations? We see wasps studiously examining localities; we find that they are lost if such studies are neglected. We observe that they are guided by particular landmarks, and that if we make a change in these landmarks the result is to confuse the wasp. Further we find that they remember places, and that memory lasts a considerable time. All these points force us to conclude that the mental operation employed by these insects is essentially the same as that used by man.

Evidence from Ants

I pass to some observations on ants. Their return to the nest, like bees to the hive, is an indication of some kind of memory. Many ants certainly scent their way back, but this will not fit all observations. For instance, *Messor barbarus*, when burying its dead, carries them away a great distance, then finds its way back by a route different from its outward path. Memory must play some part in this capacity to find the way back.

The way in which ants found new colonies implies the possession of some degree of memory. I met with two of their methods in India.[1] *Myrmecocystus setipes* sends out scouts. These scouts explore the neighbourhood, find some place suitable for nesting, and return home with the news. They then start carrying off their comrades. A scout seizes hold of a companion, tucks the burden underneath its body, and marches it off to the new nest. Now this implies that the scout remembers the place where it had found the nest. For it does not go back along the track that it came in. Also the distance is

[1] *Naturalist in Himalaya*, p. 53.

often considerable. I followed one which carried its comrade 72 feet.

Another method is for the scout to make a party fall in behind it. This is the plan of *Camponotus compressus*. The scout finds a new nesting-site, goes back to its comrades with the news. A group of comrades gathers behind it. Off they go to the new nest. The scout leads, the comrades follow; there may be twenty or thirty of them, yet all advance in a disciplined line. Frequently they meet with trouble. Objects of all kinds check their progress. Nevertheless the scout, by its efficient memory, gets its party to the exact spot.

I tried to test the duration of their memory. The species involved is *Camponotus compressus*.[1] How long can it remember a place? I fix a stick in the ground 8 inches from a nest. On the top of the stick I place some food. An ant comes and I mark it with paint. It carries away a mouthful of food, and comes back repeatedly for more. When it is well acquainted with the route, I remove the stick and go away. I come back in twelve hours, replace the stick, throw a dead insect amongst the ants in order to make them search about. The ants come out, and in the midst of them I see the one with the spot of paint. They all run about aimlessly, but the one with the paint goes straight to the stick and quickly runs up to the top. The thought of food has recalled to memory its experiences of twelve hours before. I again remove the stick, and go away for twenty-four hours. I replace it and excite the ants. The painted one again appears. For three minutes it runs about undecidedly, then it finds the bottom of the stick and climbs up to the top. Thus ants have a good topographical memory. It lasts at any rate for twenty-four hours.

[1] *Naturalist in Hindustan*, p. 69.

An experiment by Rothney extends it to a week. He worked with *Diacamma vagans*, another Indian species.[1] He made a kind of island near a nest. The island consisted of a brick surrounded by a sheet of water. By means of a stick he could bridge the water and connect the nest with the brick. One Sunday he put some sugar on the brick and connected up the bridge. An ant came across. He marked her with paint. He did nothing more till the following Sunday. Then he again connected up the bridge and the marked ant again came across it. This became a week-end amusement. Each Sunday he replaced the bridge, and on each occasion the marked ant came across it. No other ant ever crossed over, so it was clearly a case of memory on the part of this individual ant.

Can their memory last longer than this? We get on more uncertain ground. Nevertheless there is reason to suspect that it can last a year. I do not rely on Lord Avebury's experiments. These consisted in dividing nests and then bringing together the separated halves after prolonged periods of time. The ants almost always recognized one another. It of course suggests that they remembered, but the problem is confused by blood relationship. The ants may have a special communal odour; it may be that a commune has some special signal. At any rate, such things complicate the matter. More than memory may be involved.

But Belt in Nicaragua[2] made an observation which suggests that ant-memory lasts a year. Belt's garden was invaded by leaf-cutting ants. With the intention of evicting the ravagers he flooded the nest with carbolic acid. They decamped, and established themselves in another site about 200 yards distant. Twelve months

[1] *Journ. Bombay Nat. Hist. Soc.*, Vol. V, p. 38.
[2] *Naturalist in Nicaragua*, p. 62.

later they again arrived, but occupied a different part of the garden. He gave them another flooding with acid. As before, they decamped. But where did they go to? To the nest which they had occupied on the previous year and from which they were originally expelled. Belt believed that the ants remembered, that their leaders recollected last year's nest and directed the evicted commune to it.

All this implies a memory of places, and one of no short duration. But we can go a step further. We can show how a delicate gleam of judgment directs and illuminates the act of memory. Forel, is the authority on this point. Ants belonging to the genus *Polyergus*, make fierce attacks on the genus *Formica*. They seize the pupæ of the vanquished *Formica*, carry them off and bring them up as slaves. This amazing act is, of course, instinctive. But witness the memory and judgment involved. *Polyergus* makes its attack. It may have to go 40 yards or more before reaching the enemy nest. It routs the enemy, plunders the pupæ, carries them back to its own nest. Now we come to the point of interest. One raid may finish the business. On the other hand, there may be subsequent attacks, either on the same or on following days. Now what dictates these subsequent attacks? Merely the fact of whether pupæ have or have not been left behind. If the nest has been emptied by one raid, then the ants do not repeat the raid. If, on the other hand, pupæ have been left behind, then the ants return to get them. What is the conclusion? One, that the ants possess memory; otherwise they would not return for the pupæ. Two, that this memory is guided by judgment, for the ants return if pupæ have to be collected, otherwise they do not. Some image of the location of the nest plus some image of the pupæ contents must remain imprinted in their minds.

Evidence from Beetles

Dung-rolling beetles remember their balls. At least, they can leave their property for a little while, wander about in the vicinity, then return to the ball. It indicates some traces of memory. But I possess no evidence to show if this memory is lasting or not.

Something better can be found in ladybirds. These insects hibernate through the winter. Sometimes they get into houses and hide in the crevices of ceilings and walls. When the room is warmed they come out. They fly round the room, enjoying the warmth. After some hours they settle down again, and go back to the exact crevice which they had occupied before coming out. This shows that they possess a memory of places, and one that lasts for a few hours.

Evidence from Spiders

Some interesting evidence on this point is supplied by those excellent observers, the Peckhams.[1]

Lycosids are wandering spiders which drag about their egg-bags attached to their spinnerets. The Peckhams determined to test their memory. How long would the spider remember her egg-bag? Will her memory last an hour or a day?

They first tried the genus *Pirata*. They robbed its egg-bag. The spider was discomfited. They gave it back after 1½ hours. The spider accepted it. Memory lasted for that short time. Again they robbed it, and this time gave it back after three hours. The spider took it, but less readily than on the first occasion. It seemed that after three hours memory was being put on the strain.

[1] *Journal of Morphology*, Vol. I, p. 398.

They went a step further with the same species. An egg-bag was removed for thirteen hours. The spider accepted it. Another for sixteen hours. The same result. Others were kept for twenty-four hours, and of these one refused to take it back. Here, therefore, we find memory failing. Also we note the individual difference. Memory, like everything else, varies ; in one it is better, in another worse.

Then they tried the genus *Lycosa*. They kept an egg-bag for twenty-four hours. The spider took it back. They kept a second one for forty-three hours. After this time the spider seemed to have forgotten it. She touched it with her legs, but only languidly. In the end, however, she did take it back. They kept a third for forty-eight hours. She refused to recognize it or have anything to do with it. Memory had run its course.

We set out to prove that insects had memory. It was necessary to do so. Without some trace of memory there can be no such thing as learning by experience. Moreover, distinguished authorities deny it. What does Bethe say ? That insects are mere automatic machines. What does Loeb say ? That insects have neither sensations nor consciousness, but react in a manner analogous to plants.

Automatic machines ! What about the wasps' locality studies, the careful circlings, the topographical inspections, the sure return when these are performed, the failure to return when they are neglected, the confusion of the wasp when the landmarks are changed. Strange action indeed for a machine. Odd behaviour for a mindless automaton. Why, the picture is the very reverse of machine-like, the absolute and complete antithesis of automatism. Machines do not remember. Machines do

not vary their actions indefinitely. They react undoubtedly. That is their business. But what reaction? Always the same to the same stimulus. We can tell beforehand exactly what will happen. The same stimulus, the same result. Were it not so we could not trust the machine. Imagine comparing the insect to this. Strange machines these insect machines. Machines that see and reflect and remember, that use the essentials of mind as their guide.

Plant-like reactions! Equally hopeless. What about our ant behaviour? An ant gets food. After twenty-four hours it remembers the place. Each week end it is given a bridge; each week end it remembers to cross it. Is that plant-like? Can anyone maintain for a single moment that this is the behaviour of branches and leaves? Of course not! Insects are not plants, neither are they machines. We cannot explain psychic phenomena by reducing things to physical and chemical laws. Even insect psychology has something else. It has memory and conscious mind.

CHAPTER XVII

THE UNKNOWN SENSE

One portion of our subject is yet untouched. Moreover, it is one that defies explanation. Insect psychology continually surprises us and produces the unexpected at every turn. As a rule, however, we have an explanation. The chapters in this book are full of explanations of why such and such behaviour takes place. Nevertheless, there is a residuum. Something is left over which defies explanation. We find ourselves against a brick wall.

I must say just a word on insect senses. By many experiments we could easily show that insects have senses similar to our own. They can see, hear, feel, taste, touch, though in immensely varying degrees. Even when we go to more obscure senses we find indications of their existence. We have evidence, for instance, of a temperature sense when ants transfer their larvæ from colder to warmer parts of the nest. Cold has the effect of making ants sluggish. Those which I observed close to Mount Everest were infinitely more lethargic creatures than their representatives at lower heights. Then we have proof of a sense of pressure. Dung-beetles feel the weight of their loads. I could give different experiments to show that these insects recognize heaps of dung by the pressure of the substance on their backs. Undoubtedly insects have some sense of pain. It cannot, however, be very acute, for if we cut off the abdomen of an ant the creature will very soon sip up honey just as if nothing

had occurred. It even appears that insect senses are, in some ways, more elaborate than our own. I have reason to believe that *Pheidole* ants can distinguish by their amazing sense of smell every separate individual in the nest. I strongly suspect that certain Termites can hear sounds that are beyond our range of hearing; and ants are sensitive to ultra-violet light to which we are completely blind.

But this is not all. There is reason to think that insects possess some faculty different not only in degree, but also perhaps different in quality from any faculty that exists in us. Certain acts of behaviour are beyond explanation. We call in the aid of an unknown sense.

Insect Migrations

Here is something which defies explanation. Locusts habitually migrate in swarms. Without any guidance that we can see, they persist for days in the same direction, cross arms of the sea, surmount ranges of mountains, go on these migratory flights far out of sight of land. I have met with them at sea on different occasions. One time locusts came on board our ship when steaming up the Red Sea 73 miles from the African and 87 from the Arabian shore. It certainly is not vision that guides them. Though out of sight of land, they keep a true course; also their migrations continue through the night. How do they do it? What directs them on a true course across the ocean in the darkness of night?

Better still take the locust of Northern Africa. Its home is the Sahara. In Spring the full-grown locusts assemble. Off they go on a journey northward, reach Algeria and the Mediterranean. Their progress ceases. They lay eggs, and a new generation comes into being. What do the new generation do? They assemble,

migrate southward, and thus get back to where their parents came from. In this we have a remarkable instance. The young insect goes southward; when grown up, it goes northward; the impulse is to go in different directions at different periods of life. In what way can this be explained? Have they some kind of hereditary memory? Or must we postulate a new sense?

It is very much the same with butterflies. They have been met with far out to sea. I have already told of an immense migration which persisted for weeks in one direction across the Himalayan range. By what sense were they directed over great precipices and across the snow-line? Or how do the swarms keep their fixed direction across the immense plains of India? I once travelled by train for 100 miles through one of these migrating swarms. The flow continued day after day. Millions and millions of butterflies must have passed, and always in the same direction, always to the South-east. By what sense were they directed, day after day, in that illimitable tract?

It is the same all over the world. How do foreign butterflies immigrate to Britain? What is it that guides Red Admirals and Clouded Yellows at those times when they literally visit us in storms? Or how do the swarms of *Terias lisa* get from America to the Islands of Bermudas across 600 miles of ocean? How are they guided? By the sun? By the winds? By some magnetic sense?

We think of the analogy with bird-migration. Not that it helps us to an explanation. Nor, indeed, is it a fair comparison. For with birds there is a double journey. The migrants depart, and again return. Memory or education may have something to do with it. Conceivably birds may learn the route. But with butterflies there is no return journey. Hence memory is out of the question. Their migration, or rather emigration, is made

only once in their lives. What guides them is completely beyond explanation. We can only think of some unknown sense.

Evidence from Ants

My own experiments on this particular point have been made chiefly on ants.

Ants, as is well known, have a good sense of smell. It is smell, I am certain, which guides the activities of the numerous species that live on the ground. Plenty of evidence could be given to show that ground-haunting species follow scented tracks. But when we turn to tree-haunting species we find that they possess something additional. They have some guide more powerful than scent. The wanderings of tree-ants are very complicated. From branch to branch, from leaf to leaf, they are incessantly changing direction. Their life is one of turning and twisting. And in order to meet these continual changings they possess a particular sense.

A few experiments will show what I mean.

Experiment 1

Camponotus compressus is an Indian tree-ant. It nests at the foot of a large tree, sends its armies into the foliage where they wander about in search of food. Now, let us see what guides them in their searchings. An experiment is made, as shown in the diagram. A is the nest, B is the tree-trunk. C is a rod stuck in the tree. D is another rod fixed to C. E is a platform at one end of D. The rod D is fixed to C by a pivot which permits the rotation of D.

Ants are coming out of A and are wandering up the tree. I place some food on the platform at E. I put

an ant to it. It picks up a bit of food, finds its way across C, thence down the tree to the nest. It comes back for more, and after a few journeys learns the route between A and E. When it is in the nest I rotate D. I turn it through 180°. The platform E is now below. The question is, "What will the ant do?" It will come across C on its way to the food. But after that what will happen? Will it go up, or will it go down? In other words, will it be guided by scent or direction? If it goes down, it will be guided by scent, for that limb of D which it previously travelled is now turned down. If it goes up, it will be guided by direction, for that is the direction which it previously followed. What does it do? It crosses over, and without hesitation immediately goes up. Reaching the top, it finds nothing, and, in consequence, seems very surprised. I repeat the experiment again and again. Always the same result. No matter how I turn the stick, the ant always goes up. It is not, therefore, guided by scent, but by some feeling that, when it crosses C, its food lies above it and it must go up. We have here a directive impulse which is stronger than the sense of smell.

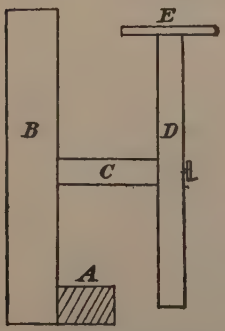

FIG. 35.—Experiment to prove Directive Sense of *Camponotus compressus*.

A. The nest.
B. The tree trunk.
C. Horizontal rod.
D. Vertical rod.
E. Platform.

Experiment 2

The Indian Red Ant, *Œcophylla smaragdina*, supplies further material for experiment. This ant builds a nest in the foliage. From the nest a long line of ants emerges

and winds about in the most complicated manner all over the branches of the tree. How does the column find its way? They do not move in an aimless manner. Each ant in the column knows its course and keeps to the fixed path. The column is all the time turning and bending, from leaf to leaf and from branch to branch. How can each ant find its way along such an infinitely complicated route?

I began by putting sight out of account. Round one of the branches traversed by the column I wound a band of white cloth. The ants crossed over it. I allowed it to remain for twenty-four hours. The ants by then had got quite used to it. If they had been guided by sight it would have been an important landmark in their path. I removed it on the next day. Were the ants disturbed? Not in the slightest. The sight of landmarks has nothing to do with their wanderings through the tree.

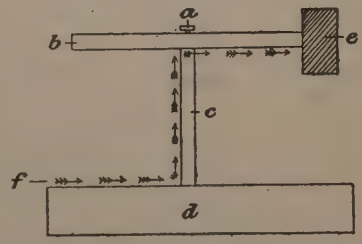

FIG. 36.—Experiment to prove Directive Sense of *Œcophylla smaragdina*.

a. Pivot.
b. Horizontal limb.
c. Vertical limb.
d. Branch of tree.
e. Byre.
f. Arrows indicating direction of stream of ants.

I then made the following experiment. E is the nest. D is a branch of the tree. C is a rod stuck in the branch. B is another rod at right angles to C. A is a pivot which permits the rotation of B on C. The ants, in getting from D to E, have to travel along the two rods. A line of arrows commencing at F shows the course that the ants take.

The apparatus is in position. The ants are travelling in the line of the arrows. I allow them to go on for two

days so as to make them quite familiar with the route. I then thoroughly wash the left half of B in order to remove any possible scent. Now see the position of things. The ants are working on the right half of B. Thus the right half is scented and ends at the nest. The left half is unscented and ends in the air. I now rotate B through two right angles. Things are reversed. The unscented limb leads to the nest, the scented limb ends in the air. What do the ants do ? Which limb do they follow ? If they go right, they are guided by direction. If they go left, they are guided by scent. Let us see. I follow the course of twenty ants. Nineteen of them turn to the right. Only one happens to go astray by wandering to the left. The conclusion is quite clear. The sense of direction, the unknown sense, is far superior to the sense of smell.

Must we look for a special explanation for all this ? Is it not enough to ascribe it to memory ? The ants, having previously traversed the route, will remember where and how they must turn, up or down, to the right or left, just in the same way as they turned before. It all sounds easy enough. It will do all right for a simple journey, a journey of say eight or ten turns. But how will it explain a complicated journey, a journey of say a hundred turns ? For these Red Ants make the most intricate journeys, traversing each branch, investigating each leaf, exploring the whole canopy of foliage in their ceaseless searchings for food. In these journeys they are everlastingly changing direction, turning now here, now there, yet never losing the road. What a feat of directive memory ! What a wonderful process of unconscious registering ! Can the ants keep a record of these hundreds of turns locked away in their tiny brains ? Perhaps so ! But if they do, how amazing is the faculty ! We are up against a directive feeling which qualifies as a new sense.

Experiment 3

Those ants which make roads over the soil are endowed with the same mysterious sense which is quite inexplicable to us. I refer particularly to *Messor barbarus*, a species which in India collects seeds and stores them inside its nest.[1]

For the ordinary comings and goings of this ant smell supplies a sufficient explanation. The ants work along a made road which connects the nest with the food-collecting area. All the ants have to do is to smell along the road in order to get to and from the nest. So far, so good. But what will happen if they leave the road, if they are forced to go in a direction quite away from the scented track? In such a case they possess some guide other than that of smell.

This is well shown when they bury their dead. I killed twenty of these ants and gave them to their comrades for disposal. The funeral ceremonies soon began. Ants took up the dead bodies, and began to carry them off. I kept special watch over one of these undertakers. It started from the nest opening and struck a course due west. It carried the dead body for 60 feet, then laid it down in the selected place. All kinds of obstacles opposed its progress, bits of stone, tussocks of grass. It had to make numerous deviations in order to get round various impediments. Repeatedly it had to let down the corpse and pick it up again. Nevertheless, in spite of all these hindrances, it maintained a true westerly course. All the other corpse-bearers acted in the same way, and pitched their burdens in the same spot. They refused to deviate. All maintained the westerly course.

How did they keep to this true direction? What prevented them from swerving to the north or south? Again, how did they find their way back? Was it by

[1] *A Naturalist in Himalaya*, p. 27.

scent? Did they retrace their outward paths and find their way back by smell? Certainly not. They returned by another route, often a couple of feet from the outward one. It was not scent that guided their return. Was it sight? Did they get back by remembering landmarks? Again they did not. When they were returning, I put objects in front of them—books, big stones, bits of paper, instruments, all kinds of things that they had never seen before. But the ants were in no way confused. They swept past my objects and kept straight on. Moreover the ground, I feel sure, was unknown to them. They always went south for their seeds. No doubt they had chosen the west for their cemetery because it was deserted ground. But how did they traverse this unknown waste? Not smell, not sight. Was it by the sun, by the wind, by some magnetic sense? All I can think of is the ants in the foliage. They seemed in some way to feel their direction, to obey an impulse to go east and west.

Experiment 4

Here is another thing equally inexplicable. *Camponotus compressus* is a powerful ant. As a rule, it carries off whatever it captures, but if the object is too heavy it summons a party from the nest to help it. Put briefly, its method is as follows.[1] It finds a large object, fails to move it, races back to the nest for help. It goes indoors, comes out in a minute with six or eight others following behind it. Away they go in military order, the ant that discovered the object leading, the others following in single file. They go quickly and with marked decision. The discoverer leads his following party without fail to the desired spot.

Now the point in this which is difficult to explain is

[1] *A Naturalist in Hindustan*, pp. 55–7.

how the discoverer gets back to the spot. At first I thought that it must be by smell. Many ants certainly employ this method, but not so the leader of a *Camponotus* party. It does not go out along its inward track, but may deviate from it as much as a foot, or follow some circuitous course. It is not sight. I placed flags and stones and pyramids in front of it. But the leader was not the slightest perturbed. It ignored them and went straight on. I built a wall across its pathway. The leader led over the top. Nothing that I could do perplexed it. By some mystery it got to the place.

An interesting explanation of this kind of occurrence might be found in Dr. Santschi's theory. He pictures a succession of mental images following one another in the insect's brain. The ant leaves its nest and travels outward. The first image is one of the nest. The successive images are those of the landmarks which it meets with on its outward path. All these images successively replace one another. Each one, as it crops up, effaces the succeeding one. They are like so many segments of a telescope being closed one on top of the other. On the return journey the telescope opens. Each successive image comes back into consciousness, the order, of course, being reversed. This unfolding of images guides the insect back, and brings it in the end to the nest. The theory is delightful, simple and clear. Unfortunately it does not fit the facts. It will not explain the return of my corpse bearer. For my ant did not come back by the route that it went out. Moreover, it was not confused by objects which were not present on the outward journey. Hence the unfolding of a series of images can scarcely explain its return to the nest.

That it is not images of outward objects is shown by a remarkable observation from America.[1] *Atta fervens*

[1] *Cambridge Nat. Hist.*, Insects, Part II, p. 166.

is one of the leaf-cutting ants. Its habit is to cut leaves from trees and carry them along paths to the nest. But McCook found one that made an underground route instead of the usual terrestrial path. This underground tunnel had a total length of 448 feet. It was altogether beneath the soil, its average depth being 18 inches, but in places descending to 6 feet. Now the wonderful thing about this tunnel was that it made an almost straight course between the nest which was being provisioned and the tree which was being robbed of its leaves. How did the ants effect this? Working in darkness and underground, how did the ants keep the true direction between these particular points. We cannot imagine the visual telescope under such conditions as these.

I give up the problem. That it is one beyond explanation is best shown by the extraordinary attempts to explain it. Darwin suggests a magnetic sense, an idea in itself sufficiently far-fetched. But what can we say of Santschi's assertions. By day the ants are guided by the sun. There is nothing particularly difficult about that, for ants are certainly influenced by light. But he goes further. At night the ants are guided by the moon. When the moon shines they can traverse unknown ground, but when it clouds over they lose the route. That too may have some possibility, though it puts the mind rather on a strain. But he goes further still. Ants can see the stars by daylight. They can see them in the same way as we can see them when looking up from the bottom of a pit. Moreover, by this daytime vision of the stars the ants are enabled to find their way. Here we have something more than far-fetched, something that Fabre would call "an imagination in the last ditch."

That ants can see the stars in the daylight! It goes far beyond my powers of credibility. It explains a problem by creating a bigger one. I prefer the unknown sense.

Evidence from Beetles and Others

Experiment 1

Certain beetles that roll balls of dung do so in a fixed direction. Again we ask, what is their guide? Here are the facts. A crowd of beetles, *Gymnopleurus miliaris*, are busy on a pad of dung. They are shaping balls and rolling them away. We soon observe that they roll their balls in undeviating lines away from the pad. One goes north, another south, another east, another west. But the point is that they refuse to deviate. In whatever direction the beetle starts it continues that direction to the end of its roll.

Now, this instinct of direction is very stubborn. The insects refuse to be turned aside. I try in every way I can think of.[1] First I attempt to perplex them with obstacles. They make their way round them and carry on. Then I try moving the beetles about. I lift a pair along with their pellet, and put them down in different places. First I move them 6 inches to one side, then I bring them back 6 inches on their path, then I advance them 6 inches forward. The result is always the same. The beetles carry on.

I even construct a rotating platform over which the insects must roll their balls. When they are on the platform I rotate the apparatus. I can make them face in any direction. Will this confuse the directive sense? I begin by turning one through a quarter of a circle. The beetle, going east, is made to face north. What happens? It wheels back and continues east. I turn another through half a circle. It was going east. I turn it west. What happens now? It twists completely round and carries on as before to the east. I twist another through three-quarters of a circle, another I rotate several times,

[1] *A Naturalist in Hindustan*, pp. 271–3.

to another I give an alteration of circlings, some to the right, some to the left. It makes no difference. Always I get the same result. The beetles persist in the direction that they started in. Do what I will, they get back to their course. How can we explain it? We make the usual speculations, but fall back on some directive sense.

Experiment 2

I pass to another illustration that impressed me. There is a large white oval-shaped bug known to science as *Monophlebus Stebbingi*. It is a familiar object on trees in India. The females, which alone concern us here, look like inert, almost motionless lumps, that keep sucking juice out of the stems.

It is an interesting sight when the tamarind is in flower to see the young females of this bug traversing the ground in the direction of the tree. Having come out of the soil, they seek the vegetation, and look like a swarm of snowy flakes moving slowly on tag-like legs. But the point of interest lies in the fact that the insects strike an unerring course straight for the foot of the tree. How do they manage it? Remember they have never before made this journey. It is their first since leaving the egg. Nevertheless, they do not wander fortuitously. From all directions the creatures converge straight on the one point. They have no path, nothing to guide them. They must push their way through leaves and débris, across a broken and encumbered jungle in which each must find its own way. I twist one and make it face the opposite direction, but it twists itself back and returns to its route. I place an obstacle before another. The object is surmounted and the snow-flake goes on. I sit down across their path. The swarm flows over me. Even my body will not turn them aside. I alter their positions as I did

the beetles. For a little time they are confused, but they always get back to the old course.

How do they do it? What keeps them from going astray when making this journey over the soil? Sight, of course, one answers immediately. But what kind of sight have these crawling lumps? I doubt if they possess the very slightest. They certainly could not see the tree. I wave objects in front of them at the closest quarters. They are quite unable to see any movement. Their behaviour suggests that they are almost blind. Is it smell? I drop in front of one a little oil of anise-seed. Does the smell disturb it? Not in the slightest. I put before another a lump of camphor. The insect treats it as if it were a stone. I try oil of eucalyptus, which is stronger and more pungent, smearing it round about the insect. The senseless creature remains undisturbed. Smell is no better than sight in explaining the movement to the tree.

What then guides the inanimate lumps? Without sight, without smell, without landmarks, without track, without any previous memory or experience, they stream in from all directions and unfailingly reach the foot of the tree. To explain it I fall back on a sense of direction, the feeling that guides ants in their movements through the foliage, and butterflies across the Himalayan range.

Perhaps it is some kind of inherited feeling. Their parents, when young, also climbed the same tree, converged in the same way to reach its foot. Generations of *Monophlebus* have obeyed the same impulse and followed the same routine. The routine is, therefore, inherited and instinctive. So will be the impulse that directs its course. But is such an explanation any explanation? We do not know what that feeling is, and we cannot explain the unknown.

Evidence from Insect-borers

Again, how do parasites, when perforating hard objects, know that their victims lie buried underneath? Take a *Bracon* perforating a tree-trunk. I have often watched these wasps in India. They force their ovipositors into a tree-trunk in order to lay their eggs in a grub.

This is the kind of thing we witness. A slender wasp crawls upon a tree-trunk trailing behind her a long ovipositor in the form of a delicate spear. She moves about examining the bark. After a time she selects one spot and there commences to bore. How does she know that this spot is suitable, that underneath is the desired grub in which she intends to insert her eggs? To our eyes the spot is no different from any other spot. Yet to the wasp it must be different. That spot alone overlies the grub. The insect cannot afford to make mistakes. Her boring is a prolonged business. It may take her almost an hour. She has to get a delicate thread-like ovipositor through half an inch of wood. That in itself is wonderful enough. But how does she know that the grub lies underneath her? What sense tells her where she ought to bore?

Again we may occasionally see a parasite perforating a mud nest. The nest belongs to a mason-wasp. It consists of a cluster of cells, all neatly built of clay, and then covered with a layer of mud. The covering completely hides the architecture. The finished structure is a smooth lump. Yet underneath the surface are cells and partitions. Stick a needle through it at any point. You may strike a cell; you may strike a partition. It is just a matter of chance. You cannot tell where the needle will go. But the parasite trying the same game can tell. There are parasites whose business is to bore into these cells in order to fix their eggs to the grub. They do so

from the outside and make no mistake. They always go straight into a cell. How is it that they manage to miss the partitions? There seems to be nothing on the surface to guide them. Yet they know the spots that lie over the cells.

I have watched wasps that are parasites on spiders act in the same unaccountable way. The spider in question makes a wonderful shelter. It bends a rush into a triangle, then encircles the triangle with threads. Within this chamber is its bunch of eggs, a compact globular heap that occupies only a small part of the chamber. The parasite, an Ichneumonid, happens to come along. She alights on the chamber, taps it with her antennæ, at last chooses one spot, and there begins to bore. Slowly she gets her spear through the rush and into the bunch of eggs. She withdraws it, gets it in again, but always makes her plunge at the spot overlying the bunch of eggs. All her perforations are done correctly. Somehow she knows the exact spot. But how she knows it is incomprehensible. To my eye the smooth uniform surface of the chamber looks everywhere exactly the same.

FIG. 37.—Parasite perforating spider's chamber.

What then is the meaning of these several observations? That these creatures appear to have some avenue to knowledge which we are unable to comprehend. I hesitate to regard it as something utterly different, of an

altogether distinct type of reality, from anything that exists in us. We must think in terms of continuity. We must not build unsurmountable barriers, and say that what lies on one side of the barrier differs absolutely from that on the other. All then we can say is that we do not understand. How insects migrate across arms of the ocean, how ants find their way when wandering through the foliage, how boring insects know what lies underneath them when perforating wood or clay ; these are problems that lie beyond us. The brick wall rises, a barrier to knowledge. Hence we postulate an unknown sense.

CHAPTER XVIII

MENTAL EVOLUTION

We can touch only very briefly on this subject. From what have these states of mind originated? How have intelligent and instinctive actions come to be what they are to-day?

Origin of Instinct

Fabre had a very simple answer. For him intelligence was non-existent, at least so far as the insect was concerned. The insect "has no choice what it shall do"; it possesses "no guide but the unconscious promptings of instinct." Hence the origin of intelligence did not concern him. What, then, was his view of the origin of instinct? His view was that no such question was possible. For instincts had no history behind them. They did not grow and develop gradually. They came complete in all particulars. The past added nothing to them; the future will find them exactly the same as they are to-day. "Whence then does instinct come, if not from the universal knowledge in which all things move and have their being."

We think that it is scarcely necessary to counter seriously this rigid view. That anything in this world is unchanging and unchangeable, that anything remains permanently exactly what it is conflicts with those unquestionable evolutionary principles which permeate

the whole of Nature. There is growth and change and development everywhere, "in heaven above, or in the earth beneath, or in the waters under the earth."

Rather than contend with Fabre's unchangeableness, it will be more advantageous to consider how instincts have grown to what they are to-day. We are up against the immediate difficulty that instincts leave no traces of their history. I mean we have no fossil instincts, nothing analogous to the records of the rocks which throw so much light on the evolution of structure. We must look for some clue to the line of evolution in behaviour as it exists to-day.

We are likely to get a ray of light if we look to what happens in our own development. Those habits which in us become automatic are very closely related to instincts. I do not say that habit is instinct, but that automatic habits so resemble instincts that we can scarcely differentiate between them. Darwin saw clearly their practical identity. "If we suppose any habitual action to become inherited—and I think it can be shown that this does sometimes happen—then the resemblance between what originally was a habit and an instinct becomes so close as not to be distinguished."

Bearing this almost identity in mind, let us ask how automatic habits have originated. Take a few of the simplest examples.

First take the habit of blinking the eyes when an object is suddenly brought close up to them. How has that come into existence? The infant at birth does not blink in that way. The act develops with experience of the world. We must picture the child first doing it deliberately because of incidents in its earliest life. Later the behaviour becomes automatic—we might almost say it becomes instinctive—so much so that it comes into action even when opposed by the conscious will. What, then,

is the source of this special activity ? First it is brought about designedly ; by persistent use it becomes automatic. In fact, what began in a learning by experience passed into what is practically instinctive.

Take another act. A boy takes to riding a bicycle. How does he do it ? By a process of learning. There is memory, concentration, judgment, deliberation, in fact all the essential factors of intelligence associated with the learning act. The boy gets older. He becomes adept. What happens then ? His cycling grows to be automatic. It is as easy to him as walking ; it becomes almost an unconscious act. But how did it originate ? Like the blinking of the eyes, in deliberate acts which clearly required intelligence.

We find indications of this even in the highest activities of life. The orator has certain tricks of expression. They are unconscious : they occur automatically, but they began by being learnt. The soldier, the sailor, the doctor, the parson has each his own professional mannerisms. They are unconscious, part of his make-up. In fact he may scarcely know of their existence. But how did they begin ? By some process that was intelligent. Either they commenced in imitation or they were learnt by design.

So this is what we find in ourselves. That those actions which come closest to instinct—so close that their working seems essentially similar—have had their foundation in deliberate efforts. In fact, automatic behaviour has come from behaviour that was first intelligent.

Of course it is a valid objection that this species of automatic action is not in the strictest sense an instinct. Instincts, we have seen, are of racial origin ; they are born with the individual. Automatic habits, on the contrary, commence and get fixed during the individual's life. Nevertheless, they come very close to instinct.

They are automatic and unconscious. In fact, they represent in the development of the individual what instincts are in the development of the race. Now, we know that individual development is a rough epitome of racial development. Hence will the development of individual automatism suggest how racial automatism has evolved.

What, then, does it suggest ? That instinct began in a reasoned act. That this act, through being continually repeated, tended to lose the reasoning element and to become more and more unconscious. As this process continued through generations, the mental machinery by which it worked got more indelibly engraven in the mind. And in the end it became automatic—in other words, it became instinctive. Of course we must not forget the fact that any evolutionary process of this kind will be subject to the laws of Natural Selection. If the instinct is useful it will develop ; if it is harmful, it will disappear.

In the nature of things it cannot be demonstrated that this has actually taken place. Creatures die ; they may or may not leave some record of their structure, but one thing they cannot leave is any trace of their old instincts. But we can see how this mode of development might easily have been brought about. I mentioned an ant found at Tenby, which, when its nest was in sandy surroundings, deliberately built a crater at the entrance. That was a special intelligent deviation. But if it happened to become advantageous to the species, owing, let us say, to a change in the environment, to act in the same way as the nest at Tenby, then the crater-building instinct would become generalized. By continual repetition it would lose its deliberateness and end by becoming automatic or instinctive. Or take that ruse of the *Mellinus* wasp to capture the wary flies at Bournemouth. It lay on the cow-dung, simulated death, and waited for

the prey to walk into its clutches. Now this again was a deliberate device to catch flies which were unusually active. But if flies in general became more active, then the simulating habit would no doubt become more widespread. The species would adopt it everywhere, and by repetition it would grow instinctive.

Of course this view will be immediately rejected by those who see in the insect world no sign of intelligent behaviour. But I am confident that intelligence exists. In fact, not only do I find intelligence, but I regard the deliberate acts of intelligence as the source of every instinct.

Evolution of Instinct

If we cannot demonstrate with absolute certainty the source from which an instinct has originated, at least we are able to point out the steps along which it probably evolved.

Take the first instinct mentioned in this book, that wonderful instinct where a single ant despatches an army to retrieve spoil. Can we detect the successive stages in the growth of that remarkable behaviour? I think we can. In India I observed a series of habits which show how this elaborately perfect act can have grown from simple things.

First recall the perfect instinct as displayed by *Pheidole* ants. A single ant discovers spoil. It races back to the nest with the news. In a few seconds out comes an army which dashes off in the direction of the spoil. But the amazing thing about it is that this army needs no direction. It is not led by the ant that brings the news, but follows out along the track which that ant leaves on the soil. It finds the spoil by its remarkable capacity of retracing a scented path. Now this is the very height

of efficiency. An ant arrives, proclaims news, and, without its co-operating any further, an army advances and recovers the spoil.

In order to determine how this has developed, let us see what happens in some other species.

An Indian ant, *Camponotus sericeus*, will show us the earliest rudiments of the act. This ant nests on the ground and goes up trees in search of food. Its plan of communication is very simple, and, being so simple, is highly instructive. All that happens is that one ant leads another to the place where spoil has been found. One ant discovers spoil. It returns to the nest, finds a comrade and leads it to the required place. The two go off over the ground. The leader keeps in front; the led ant follows. Number two keeps in number one's footsteps, and repeatedly touches its tail. The leader moves particularly slowly in order not to lose connection with its follower. If number two happens to get out of touch, then the leader halts and waits until number two regains its place. Then they start off again, one leading, the other led.

This is the instinct of calling out the army in its most rudimentary state. It is just one ant leading another, and the bond between them is merely touch.

Turn now to *Camponotus paria*. This ant will take us a step further. As in the previous example it is just one ant leading another. But we notice a few slight, though important, differences. The led ant does not keep so close behind its leader. It often falls 2 or 3 inches in rear, yet does not lose its way. Also we see none of the repeated touchings; nor does the leader halt and wait if the led ant goes a little astray. In fact, as I have proved by a series of experiments, it is not by touch that the led ant follows, but by the sense of smell. So here we have an advance in the instinct. The mechanism is

freer, the two ants are more independent of one another, above all the following by touch has disappeared and has been replaced by scent.

Turn now to *Camponotus compressus*. This one will take us another step. An ant finds spoil and goes for assistance. But it does not bring only one companion. It summons out a small party which collects in a group behind it. Off they go in the direction of the spoil. The summoner of the party acts as leader ; the remainder, some ten or twenty in number, follow in single file. All keep in one another's track, which they recognize by means of scent. Here, then, we have another step onward. The solitary follower has become a group of ants.

But this ant can show us another link in the chain along which evolution has occurred. I refer to the way in the finished instinct that the army retraces the scented track. For when one of these ants is returning with news it often meets with a comrade on the road. What happens then ? The incoming ant goes on to the nest. The comrade, however, turns about, retraces the track of the incoming ant, and, if the distance is not too great, manages to find the spoil. Here then we have another link. The capacity to retrace another ant's track appears in a rudimentary state.

Then we come to the finished instinct as shown by *Pheidole indica*. All that is necessary to bring this about is to improve the last example. There is no need to introduce any new principle. It is just a matter of improvement. Increase the issuing party into an army ; improve the faculty of smell from the power to retrace a path just a little to one of retracing its full length ; also speed up the whole process and the result is the finished instinct as observed in *Pheidole indica*. And here we seem to have supreme perfection. For the moment

a discoverer enters the nest, out pours the issuing legion which retraces the track till it reaches the spoil.

Thus what seems to be an act of considerable complexity can be shown to have developed by simple steps. It commenced by one ant leading out a comrade and keeping up contact by mere touch. This, of course, was primitive and inefficient. But considerable improvement came about as touch gradually gave way to scent. More ants then began to join in the business. The solitary follower became a party. At the same time the olfactory faculty improved. First it was a follow-my-leader kind of scent. Then the ants learnt to retrace a short path. In the end they reached a stage where a vast army could retrace the whole path of a single ant. Hence it is possible to detect the steps by which instincts have grown to be what they are.

Convergent Evolution

When we meet with instincts similar in plan we naturally assume a common origin. And in the vast majority of cases there is little doubt that the asumption is correct. We see different species of honey-bees possessing the instinct to make some type of comb, we see different species of hunting-wasps possessing some form of the paralysing instinct; we see different species of spiders possessing some kind of web-making device. What do we say? That the creatures possess the same plan of instinct because they came from a common ancestor. They brought with them the ancestral instinct. Certainly with each species it has altered in detail, but still we see the common principle, the same ancestral plan.

Now this is all quite clear and simple with respect to creatures not too distantly related. But what can we say when we find similar instincts in creatures whose

relationship is immensely remote, so remote, in fact, that under no conception, could these instincts have had a common origin. Yet of this there is one very striking example, the development of a complex social organization in the two groups, Termites and Ants.

The entomologist immediately appreciates the immense difference between these two groups. For the reader who is not an entomologist some explanation must be given. The ants are related to bees and wasps; they come under the Order Hymenoptera. The termites are connected with may-flies and dragon-flies, that is the quite different Order Neuroptera. The Ant is, in fact, a kind of wingless wasp; the Termite a primitive cockroach. If we were to draw a rough parallel, we might choose the furthest extremes amongst mammals, and say that the difference between termites and ants is as great as that between opossums and man. Now it is an extraordinary thing to find in two groups so immensely distant a highly elaborate social organization evolved on similar principles and working on an almost identical plan. As Wheeler remarks on this particular point, it is as though, when Australia was discovered, the explorers had found opossums in the island with a social organization comparable to that of man.

This is what we speak of as Convergent Evolution. A common origin is out of the question. We must regard the two groups as if they were two separate discoverers that had hit independently on the same inventions. Let us see what a crowd of inventions these creatures have succeeded in discovering independently. I will confine myself to those which have come under my notice in the Tropics.

First, of course, there is the caste system. A termite commune is highly complicated. It has kings, queens, soldiers, workers, organized on almost the same principle

that we find in a community of ants. Then both have hit on the same plans of nest-making, either a subterranean system of chambers or a structure in a tree made of chewed-up wood. Then both have taken to keeping lodgers. These are other insects of numerous varieties which live permanently with them in the nests. Then they both have discovered that amazing habit of cultivating fungi for use as food. Break open a termite mound in India and that of an *Atta* ant in Brazil. In each will be found large sponge-like masses, with myriads of fungi growing in their interstices, veritable gardens of innumerable mushrooms made and tended by the termites and ants. Is it not astounding that two separate groups should have learnt this horticultural business independently ?

But apart from this resemblance in outstanding features, we find that the minutest details of behaviour are almost identical in the two groups. There happens to be one particular Termite, the foraging species, *Eutermes biformis*, which demonstrates this in the clearest way. I observed this species carefully in India. It is a termite with open-air habits. It makes a small nest underneath a stone, and sends out parties to collect grass which they store inside the nest. Now every detail in the behaviour of this termite can be paralleled in some species of ant.

Take some of their commonest everyday acts. They dig their nests by the ant method. Gangs of porters excavate tunnels, carry out the lumps of earth and pitch them on a special rubbish-heap outside. I need not say that this is the method of almost every ground-nesting ant. Then these termites send out foraging expeditions. Immense armies make their exit from the nest, march out along a common road, cut quantities of vegetation which they gather into special vaults. This behaviour

calls to mind the leaf-cutting ants, of which armies march along well-worn roads conveying their leafy burdens to the nest. Then this termite, when at work, divides its forces. One division, composed of workers, cuts and carries the blades of grass. The other division, made up of soldiers, surrounds the workers with a military ring. These soldiers stand side by side, their antennæ touching, their spear-shaped weapons directed outwards, all ready to repel an enemy should it attempt to pierce their ring. Here we have a strategy closely paralleled by the device of some *Pheidole* ants. For they too have learnt the military circle. Their soldiers make a defensive ring while the workers carry off the spoil.

This termite is accustomed to build arcades, arched roadways under which they march when entering and leaving the nest. In this we have another ant invention. For *Eciton vastator* makes similar roadways beneath which its armies advance. Disturb these termites when engaged at harvesting. What do they do? First pour back into the nest. Then the soldiers stand guard over the entrance while the workers seal it with a barricade of stones. Again another ant procedure. We find it paralleled by *Messor barbarus*, which throws up a stony rampart in exactly the same way. Then there is the power of recognizing one another. Take away a member of the termite community and return it the next day. It is recognized and accepted as a friend. But give them an individual from another nest. Something different happens. It is treated as an enemy. Soldiers attack it, shoot poison at it, and soon have it lifeless on the ground. Is not this exactly the same with ants which live in amity with one another, but attack a stranger from another nest?

I need not labour the comparison further. We have seen that the two groups resemble one another, not only

in the same elaborate social organization, but even to an almost identity of behaviour in the smallest details of that social scheme. Is it not amazing that such complexity and detail should have come into existence independently without ever having had a common source ?

Diverging Evolution

We have seen how insects far apart in the scale can come to possess analogous instincts. There is another side to the picture. Often we find closely related insects with instincts which are obviously developing along separate and diverging paths. Observations of this kind are highly instructive. They indicate the lines along which instincts are at present becoming evolved.

Take the nearest relationship practicable, two species of the same genus. Let us see how their instincts tend to develop along diverging paths. Two wasps belonging to the *Sphex* genus, the Indian Sphex, *S. lobatus*, and the French Sphex, *S. flavipennis*, will make this point perfectly clear. The one I have studied carefully in India ; the other is the species on which Henri Fabre made some of his most brilliant observations.

These wasps are huntresses of crickets. How do they carry out the business ? They chase the quarry, paralyse it by stinging, lay an egg on it and seal it in a hole. Both wasps follow the same method. What more then is to be said about it ? The two closely related species lead practically the same kind of life.

But let us examine the matter closely. We will then observe a crowd of differences, I do not mean just casual aberrations, but differences as fixed and stable as any differences in their anatomical structure. It is these differences which are so instructive, for they will have evolved since the two species separated from the ancestral

stock. They will indicate the trend of instinct-evolution in the recent past and at the present day.

How, then, do the two species differ ?

1. First they differ in their sociability. The Indian Sphex is an absolute vagrant. She is found solitary in sandy tracts. Her huntings, diggings, killings, everything is always carried out alone. The French Sphex, on the other hand, has some social propensities. A number live and work together ; they dig their nests within view of one another. There is some trace of a communal bond.

2. What about the architectural instinct ? The Indian Sphex has no special habitation. She makes no tunnel or den of her own. She has not a trace of architectural skill. The French Sphex, on the contrary, does dig a burrow. It is a long tunnel with a cell at the end, which serves both as a shelter for its owner and a nest for the young wasp.

3. Then they differ in their roosting habits. The Indian Sphex spends the night in the trees. She goes into the thick of a tamarisk bush and hangs on to a cluster of leaves. The French Sphex is better provided. The tunnel she digs is her shelter for the night.

4. Also they differ in the quarry they hunt. The Indian Sphex chases a monstrous cricket, a victim vastly bigger than herself. It is far too heavy for her to lift; all she can do is drag it on the ground. Owing to its weight she can pull it no great distance, and must bury it near where the capture took place. In fact, after paralysing her cricket, she stuffs it back in its own den. The plan of the French Sphex is quite different from this. Her special cricket is very much smaller. As a consequence she can carry it very much farther. Also, it being light, she habitually flies with it. This gives her much freer scope and allows her to collect her captures

into one prearranged hole. Then the number of captures in the tunnel differs. The Indian Sphex has the strict rule of one victim in each tunnel. The French Sphex accumulates her captures, and a number go into the same hole.

5. What about their battle tactics ? The Indian Sphex gets her cricket by its wing, then curls herself round its flank, then makes a paralysing stroke into its neck. Perhaps the chief point about it is that she makes only one stab. The French Sphex has quite a different method. She throws her cricket over on its back, stands astride of it, belly to belly, seizes the tip of its abdomen in her jaws, then makes three separate stabs. The first goes in the neck, the second into the thorax, the third into the front of the abdomen. Each is believed to enter a nerve ganglion and have a paralysing effect. But see how different are these tactics, especially in the number of the paralysing stabs.

6. Then the type of paralysis differs. The Indian Sphex gives one staggering blow. Its result is to paralyse the cricket completely. The creature for a time is absolutely unconscious. It seems to be quite dead. The coma, however, is only temporary. After ten minutes the cricket can walk ; in fifteen minutes it is quite alive. How very different is the other species. The French Sphex paralyses permanently. Her victim may live for weeks after the stabbing, but never recovers from the paralysed state.

7. A last point is the placing of the egg. Both species put it on the cricket's breast. But the Indian species habitually places it in the space between the first pair of legs, while the French Sphex puts it further backward between the first and second pairs of legs.

So here we have two species very closely related. Yet see how their essential instincts differ. Roughly their

manner of life is the same. In detail they present a crowd of differences. It is these differences which are so instructive. They point out the lines on which instincts have diverged since the creature left the ancestral stock.

CHAPTER XIX

CONCLUSION

We commenced with the question: "Are insects the blind agents of irresistible impulse, or are they endowed with a share of reason?" We have examined the evidence in detail. Let us, therefore, supply the answer.

The Place of Instinct

Instinct, without question, is the dominating force that controls the wonderful activities of insects. This force is innate and automatic. It is born with the creature as part of its nature. The animal possesses no choice with respect to it, but must obey its imperious demands.

We have examined the nature of this force. Speaking in a broad and general sense, instinct is a force of amazing perfection. It performs acts of such precision that they sometimes seem to surpass intelligence. What can be more perfect than the spider's net with its equal angles, its uniform spirals, its nicely parallel threads? Or see the perfection in the comb of the hive-bee. Why, these creatures have solved a recondite problem. It is only a student of the higher mathematics who could determine after detailed calculations that this exquisite system of waxen chambers, with their pyramids and rhombs and particular angles, was the one and only system possible to effect the greatest economy of wax.

Thus we may grant the perfection of instinct. Nevertheless, there is another side to the picture. For instinct may sometimes be very faulty. We have seen how, in the midst of all this perfection, we occasionally meet with serious errors. An insect may select the wrong species to mate with, another may lay on the wrong kind of food-plant, another may construct the wrong type of cocoon. These are errors that run through the perfection, and their result is disaster and death.

Then again we have seen that instinct is inflexible. It battles against every obstacle in order to fulfil its particular end. We saw how locusts marched out upon a river and allowed themselves to be drowned in millions rather than change their instinctive course. We saw butterflies lost on the Himalayan snow-line in obedience to that unswerving instinct which impelled them across the range. We saw spiders allowing themselves to be cut in pieces rather than change their instinctive device of sitting absolutely still.

But as we remarked with respect to perfection, this is true in a general sense only. For as error creeps into the midst of perfection, so does a certain variability alter the inflexible course of instinct. We have had numerous examples of this. A wasp which ordinarily makes a comb from wood will suddenly take to using paper. A bee, which makes a nest of resin, sets about trying to build it of grease. A humble-bee, which normally nests in moss, goes and builds in a bundle of rags. Instinct, in the main, is rigid and inflexible, but we find much variation in the details of the main act.

Then, again, instinct is wise in its purpose. We saw this particularly in the hunting-wasps. How amazingly wise it seems that a wasp can get the end of its sting into the one anatomical point that will bring about paralysis of its prey. But, as before, the statement is only a general

one. Have we not seen the incredible folly when instinct attempts to fulfil some purpose outside the ordinary routine ?

What then can we say of this innate force ? That instinct is perfect, wise and inflexible. Yet that none of these attributes are absolutely rigid. Under certain rare and exceptional circumstances, what is ordinarily perfect may fall into error, what is ordinarily wise may become foolish, what is inflexible may vary and change. Nevertheless, in a general sense, instinct is perfect, inflexible and wise. And it is this perfect inflexible force, innate, unconscious and automatic, which directs, in the main, those wonderful activities that occur in the insect world.

The Place of Intelligence

But contrary to the belief of many authorities, I maintain that insects are not wholly instinctive. I do not subscribe to that opinion which holds that they are highly rational creatures, and that all this show of elaborate behaviour is the outcome of a high intelligence. I have said that these activities are mainly instinctive, but that running through them is a stream of judgment, Huber's "little dose of reason."

They possess a small share of intelligent activity. That activity is plastic. It is capable of modification. It is more clumsy and less perfect than instinct. It is not something inherited from previous ancestors, but something gained in the individual lifetime. Thus it is feeble when compared with instinct. Moreover, it affects the small details of behaviour rather than the main acts. If instinct be compared to a vast river flowing in a steady and unchanging course, then intelligence is like the ripples on its surface that alter with every breeze.

What can the insect do with this intelligence ? Let

us take a few of our numerous examples. Remember the purport of these examples. They are not acts of ordinary routine. They are drawn from that plastic type of behaviour which these creatures employed in exceptional circumstances to meet particular vicissitudes in life.

1. Can it *reason* from cause to effect? See what the dung-rolling beetles did when their ball was pinned with a long stake. They examined the ball, discovered the stake, then freed the ball by cutting it in half, and afterwards united the separated bits. Is not this reasoning from cause to effect? The ball had stopped, that was the effect. The beetles found out the cause of this effect, namely the stake running through the ball. Then, having learnt the cause of the stoppage, they quickly put things right.

2. Can it *adapt* means to ends? What about that wasp, *Mellinus arvensis*, which captured flies on pads of dung. Ordinarily it caught them by sneaking about, but at Bournemouth, where the flies were particularly active, it lay on the dung simulating death, and waited for the victims to walk into its grasp. Have we not here a particular plan adapted to meet a particular end?

3. Can it *reflect* on a course of action? Remember that caterpillar which jumped the basin when it was isolated and could not escape. Remember those ants in the dried-up nest that went and fetched water from a neighbouring moat. Nothing will convince me but that these creatures reflected on their course of action before doing these very exceptional acts.

4. Can it do something *ingenious*? Undoubtedly it can, and amazingly ingenious. What about the Peckhams' wasp and its hammering. A particular individual got hold of a pebble and used it as a hammer to pound its nest. Even more ingenious were Swynnerton's ants in the way they dealt with a poison-spined caterpillar.

Their ingenuity was almost incredible. First they blocked the poison-openings with crumbs of earth, then amputated the spines.

5. Can it act with *judgment*? We have seen many remarkable instances. A *Pompilus* had paralysed an unusually large spider and then adopted the exceptional behaviour of examining the mouth-parts of its victim most carefully before commencing to drag it off. Surely that act indicates judgment. The wasp judged it dangerous to start pulling unless the mouth-parts were absolutely numbed. Or better, the wasp that got its large victim to the vicinity of its small hole. It showed unquestionable judgment. It did not even try to get its victim in, but went backwards and forwards between victim and hole, formed a judgment that the victim would not fit, and then enlarged the hole.

6. Can it show *resourcefulness*? In a hundred ways. What about those wonderful bridges by which tropical ants traverse the foliage. What about the pendulous ladders they make when they wish to escape from some difficult place. We saw wasps resourceful in repairing holes, and beetles in reshaping their balls.

7. Can it act with *forethought*? I need only refer to that mason wasp which did not make just one cell after another, but laid out beforehand a foundation-plan for all the cells of the finished nest.

8. Can it *remember*? Without the slightest doubt. A particular ant remembers its food-place after a prolonged period of time. A hive-bee can retain from one season to another the memory of some particular spot. What about the locality-studies of wasps. Why, these creatures not only remember one spot, but keep in their minds a geographical picture of the territory over which they work.

9. Can it *imitate*? We saw a very good example in the

case of those two *Donisthorpea* ants. One species lives an underground life and never marches in files. The second species, on the contrary, marches in files on the open soil. But sometimes number one joins with number two. Then number one imitates number two by coming into the open and marching in files.

10. Can it *learn from experience*? Certainly it can. Perhaps the best of the illustrations is the ant-nest divided into halves. The ants in one half were treated kindly and as a result became quite tame. Those in the other half were pinched and burned, and remained ferocious to the end.

So far as I can judge from the evidence given, we are not justified in making barriers between insect and human mentality. I mean we have no right to regard their minds as being totally different in kind. In their main essential characteristics the minds of these humble creatures operate in the same way as the mind of man, and this harmonizes well with those laws of continuity, which, as our knowledge of this world grows, become more and more firmly established.

Comparison with Man

What right have we to make any such comparison? It is said that the mental state of an insect is fundamentally different from that of man. We are told that we must not attempt to examine it by the methods with which we examine ourselves. Since all we do is to observe behaviour, and since we cannot see into the creature's mind, therefore it is quite unjustifiable for us to compare that creature's mind with our own. But if we cannot adopt this method then we must give up the subject altogether. Indeed the argument against this

method would, if carried to its logical conclusion, bar observations on the human mind also. For what can we know of any other man's mind? Absolutely nothing in actual reality. We can see no more into his mind than we can see into the mind of the insect. All we can do is to draw inferences from his observed acts of behaviour. The method, we know, is incomparably successful. Every estimate of human character, which every individual makes every day, is a matter purely of inference—in fact essentially the same in nature as the inferences drawn in this present volume. Deny the method to the comparative psychologist and the human psychologist must lose it also.

Undoubtedly in the method there are dangerous pitfalls, and the greatest care must be taken to escape them. Facts are often recorded inaccurately. Still more often are conclusions drawn quite out of keeping with the facts observed. Books and papers are crowded with anecdotes, the most of which are altogether worthless because they do not come from trustworthy observers. I have tried to escape this danger by keeping to facts from unimpeachable authorities. Fabre, Ferton, Bates, Belt, the Peckhams, Wheeler, Forel, Huber, and many others mentioned in this book, are observers whose facts cannot be questioned. But I have relied in the main on my own observations spread over a considerable number of years.

I do not deny that insects may have senses which give them information unknowable to us. The discussion on the unknown sense suggests some amazing knowledge of direction far beyond the limits of our own powers. Nevertheless, I greatly doubt if these creatures possess anything altogether different in kind; the difference is merely one of degree. We may stand amazed at the ant's sense of smell; but, though more familiar, it is just as incomprehensible how a dog can pick out his master's scent along

the crowded road of a city. Great though is the gulf between the two types of mind, yet the difference, I believe, is only in degree. I believe so because the evidence supports the opinion. Moreover, to do otherwise would conflict with the great principle that psychological as well as physical continuity runs through the whole animal kingdom.

Great prejudice existed, and perhaps still exists, against admitting similar mental activities in the lower animals and man. It is probably as much to prejudice as judgment that the following assertions are made about insects. That the insect is purely a creature of instinct while man is the sole embodiment of reason. That insects are nothing but animated machines. That they possess no psychic qualities whatever. That their acts are chemico-physical in character. That their behaviour is analogous to the reactions of plants. That they lead purely reflex lives. These assertions I believe to be quite unfounded. Certainly a vast gulf exists between the human mind and that of the insect. But this gulf is a bridgeable chasm. The difference is a difference not in kind. It is a difference in immense degree.

In what then does the difference consist? Every animal, man included, possesses two sets of mental activity: the one instinctive, automatic, innate: the other intelligent, plastic and acquired. These two activities are always blended. They may differ immensely in degrees of development, but they never completely separate from each other.

The insect mind and the human mind differ mainly in the development of these two factors. Instinct predominates in the insect mind: intelligence in the mind of man. Nevertheless in both the insect and man these two factors definitely exist. But their minds have evolved along different channels. They have marched,

so to speak, along diverging paths, the one developing the force of instinct, the other the force of reason. And each has brought its own type of development to an amazingly perfect degree.

Yet the insect, though predominantly instinctive, possesses also glimmerings of reason. Exactly the same is true of man. Though his life is so filled with rational judgment, yet underneath are those primitive instincts which appear to fulfil such a minor part. Yet they exist at all stages of his life. The suckling of the infant; the playfulness, destructiveness, curiosity of the child; the desire for society and companionship of the adult; these are fundamental instincts born with the individual as part of his life. Indeed, the very highest human activities must possess something like instinct in their composition. Does the artist paint, the musician play, the poet produce his beautiful lines just because he learnt how to do it? Of course not. Learning and education have improved and perfected him, but underneath is an innate impulsive force which impels him to that special form of activity and gives him much of his wonderful powers. And in what way does that innate force differ from what we ordinarily call instinct?

Regarded then from a psychological standpoint, the brain of man and the brain of the insect possess the same fundamental qualities. They differ, however, immensely in degree, because they have evolved along diverging paths. The psychological tree has two great branches, the branch that represents the growth of intelligence and the branch that represents the growth of instinct. Man stands at the summit of his own branch and thus dominates all creation. But the insect crowns the other branch. In it instinct has reached the highest development. In fact many acts performed by instinct are as wonderful as the acts of reason.

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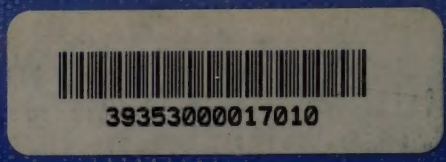
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